GIS and Remote Sensing in Identification and Change Detection of Wetland Reclamation Areas in Port Moresby, PNG

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Abstract

Wetland reclamation commenced in Port Moresby about 20 years ago, having started on a small scale and grown into a large scale following the burgeoning demands of urbanisation and industrialisation. Wetlands are identified as water-submerged areas exclusively inland and almost all the year round in areas connected to the shoreline with fluctuating waterline along with tidal movements. In this paper GIS and Remote Sensing technology are utilized to determine the temporal changes in reclaimed lands and also to identify the wetland areas. The data type used is high spatial resolution temporal data for the years 1990, 2007, 2011 and 2016. The method of feature digitisation and extraction with overlay technique is commonly used for identifying wetland areas as well as coastal reclamation areas. Findings indicate that a total land area of 580,131m^2 has been reclaimed along the coastline with economic, environmental and social implications. Residents surrounding the reclamation site experience issues such as higher impact of sea level rise, air and sound pollution, destruction of wildlife habitats and associated species endangerment. Findings of the study can assist urban planners in minimising land management and urbanisation-related problems. On the other hand, the wetlands identified during analysis and mapping are vital to the environment and to humans as they provide functions that are necessary for a healthier environment. The land use and land cover of the newly reclaimed lands have indicated some progress in urban development in and around the city of Port Moresby.

Keywords: *wetland, reclamation, GIS, remote sensing, digitization, Port Moresby*

1. Introduction and Rationale for the Study

Port Moresby has been rapidly developing since the 1990s especially in terms of infrastructure development, including roads and buildings. Over the years, Port Moresby has developed and extended its workforce in both the formal and informal sectors and as a result created a huge demand for supply of goods and services. One of the major development activities practised on a large scale is wetland reclamation. Wetland reclamation is defined as 'the process of reclaiming submerged land from water bodies like oceans, lakes, swampy areas and rivers' (Liang, 2004), and land reclamation is the process of creating new land from any water-saturated area by filling the area with either soil and large or heavy rocks. These two key activities are necessary for increasing the supply of land for further development in water-logged urban areas that are challenged by shortage of land. Wetlands are also referred to as 'kidneys of the planet' because they are essential in sustaining biodiversity of flora and fauna and are thus crucial to human existence.

Although land reclamation is vital in land development, it is also harmful to the ecosystem, the milieu of natural environment and its inhabitants (humans, plants and animals). The destruction of eco-

systems affects plants and wildlife, increases species endangerment and invites hazards such as landslides, soil and coastal erosion and sea level rise. Wetlands include habitats such as marshes, floodplains, rivers, lakes, coastal areas less than 6m deep and also waste water treatment ponds and reservoirs (Ramsar Convention, 2007). In PNG, over 80% of the 5,000 lakes lie below 40m and are mainly associated with large rivers and surrounded by extensive wetlands. Other wetlands such as mangroves, brackish swamps, freshwater swamps, and alluvial plains account for 7.5% of the total land area of the country but are known as sparsely populated regions with 2–4 persons/km^2. It is essential to understand the benefits and impacts of reclamation activities to the environment, community and economy. Government officials and urban planners can utilize findings on change detection such as the extent of reclamation occurring, and what are the environmental, social and economic impacts of reclamation to assist in decision support systems for future plans to expand urban development.

The purpose of this paper is to determine the extent of wetland reclamation activities in Port Moresby over the past 20 years through change detection analysis and to identify the impacts of reclamation activities on the environment and the community. Related objectives of the investigation are: to identify wetlands in Port Moresby, to carry out change detection of wetland reclamation, and to create a land use-land cover map of coastal reclamation activities taking place in Port Moresby.

This research applies Geographic Information Science data analysis techniques and remote sensing technology to carry out change detection study to identify changes in land reclamation in Port Moresby using high spatial resolution images of different years. Change detection techniques of manual digitization and feature extraction were employed within GIS and RS environment to identify wetlands and reclaimed lands in the city. The change detection approach adopted by Jana et al. (2014), where multiple vector layers were obtained from digitization of multi-temporal satellite data (Quickbird image and orthophoto) were subjected to overlay analysis and proximity analysis to highlight temporal changes and the impact they had caused. This method is considered to have a good accuracy and it is mainly done with very high spatial resolution aerial photographs. Object digitization is the major activity that is done for all classes in the separate images, followed by overlaying of the vector layers to identify changes occurring in the area of study.

The use of Geographic Information System (GIS) and Remote Sensing (RS) has proven to be of great utility in feasibility studies and impact, social, economic, environmental and land reclamation projects because of the ability of the analyst to incorporate and facilitate the analysis of spatial data taken from classical and modern sources. According to a Romania case study (Mihai et. al, 1918) using GIS systems to create a database for land reclamation works, it was observed that establishing the type of works and designing a database structure with technical parameters provided decision makers with a support system that allowed them to reveal, rehabilitate and monitor land reclamation works.

The second objective of this study is to identify the land use and land cover (LULC) of Port Moresby's reclaimed areas. LULC is used to describe the changes in entities on the surface of the Earth. Land cover describes the physical state of the land surface including vegetation, wetlands, buildings, roads, soil types, etc., while land use refers to the manner in which humans utilize the land and its resources, e.g. for agriculture, urban development, logging, mining, etc. (Al-doski et. al, 2013). RS technology and methods for LULC are highly desired because they are cost-effective and time-efficient (Paradzayi et. al, 2008; Nordberg and Evertson, 2003) and can be integrated with ancillary data such as maps, field surveys and ground truthing interpretation for more accurate results.

2. Materials and Methods

2.1 Data Required

Change detection requires georeferenced, multi-temporal images of the same area that are captured at different times. In this paper, very high spatial resolution satellite images for 1990, 2007 and 2011 are used to identify wetlands and for change detection analysis of Port Moresby. Satellite imagery obtained from Google Earth for 2016 is used to identify reclamation areas. The datasets used are indicated in Table 1.

Table 1: Data Used

Modified Date	**Data type**	**Scale/Resolution**	**Source of Data**
1990	Google Earth Image of Port Moresby. Image is from 1990 (Ikonos Satellite Sensor)	Spatial Resolution: 1-meter Georeferencing: UTM WGS 1984 Zone 55S	PNG UOT, DSLS
2000	DCDB of Port Moresby	1:10 000	NCD City Council- GIS Unit
2007	Birdview satellite image	Spatial resolution: 2-meter Georeferencing: UTM WGS 1984 Zone 55S	PNG UOT, DSLS
2011	Google Earth Image of POM Captured: 15/06/11	Spatial Resolution: 1-meter Georeferencing: UTM WGS 1984 Zone 55S	PNG UOT, DSLS
2016	Google Earth Image of POM Captured: December 2016	Spatial resolution: 4-meter Georeferencing: UTM WGS 1984 Zone 55S	Google Earth Software

2.2 Study Area

Port Moresby is the capital city of Papua New Guinea and the largest city in the country. It is located in the Central Province and centered on latitude 9°30′49.1″ South and longitude **147°13′7.7″ E**ast. Based on the 2011 National Census the population of PNG is 364,120 with an annual growth rate of 2.1% (National Census, 2011). Port Moresby is traditionally inhabited by the Motu-Koitabuan people and consists of three Local Level Governments (LLG's), namely: Moresby South, Moresby North-East, and Moresby North-West. There are four main Central Business Districts (CDBs) in Port Moresby, namely: Down Town, Boroko, Waigani and Gerehu. The weather is mainly wet and dry (seasons) and there are several fresh water flowing rivers and lakes. The main areas of focus are the coastlines of the city (Figure 1).

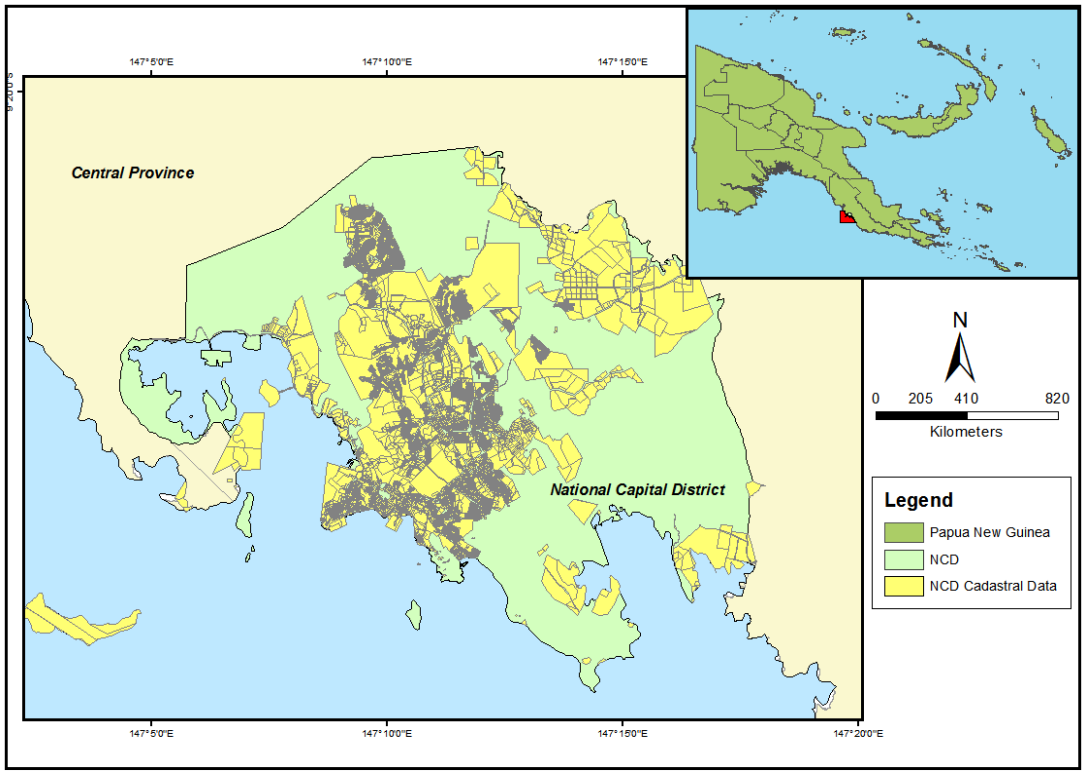

Figure 1: Location map of study area

2.3 Method

The research method for this study comprises change detection technique of manual digitization to identify wetlands and reclaimed lands in Port Moresby. The process used was time consuming but the results and output were achieved successfully. ArcGIS 10.2 was used to analyze the data and output maps generated to present the findings. The data set used was for the year 1990; this was used as the base map for the study along with several other high spatial resolution images for 2007 and 2011 to identify wetlands in Port Moresby. Recent images from 2007 to 2016 were digitized to identify newly reclaimed lands in the city through the method of change detection and fuzzy overlay technique. Comparison of reclamation land is shown in tabular format summarizing the wetland areas in square metres and in percentages to display the temporal changes in land cover. The flow chart below summarizes the methodology of the study.

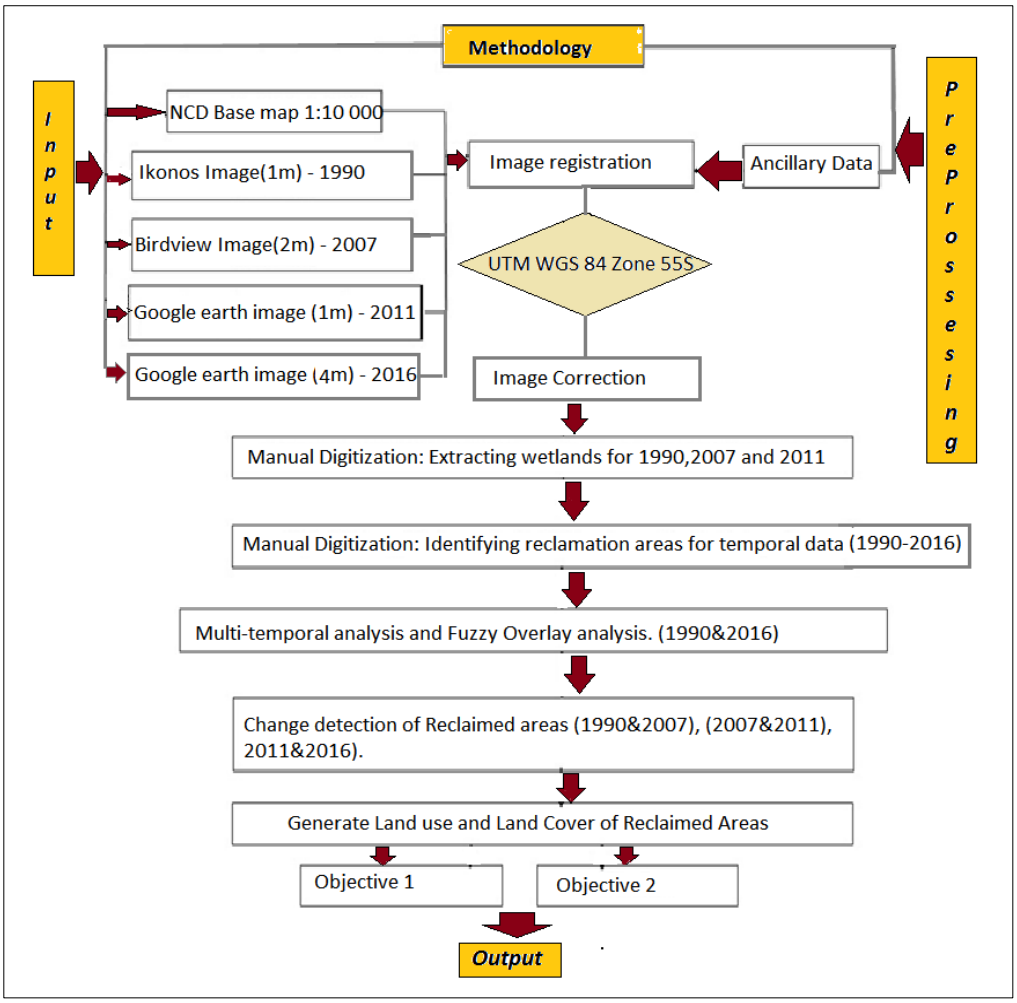

Figure 2: Summary of Research Procedure

3. Results and Discussion

The following results were obtained from the combined analysis of the 1990 Google Earth image with 2-meter spatial resolution, the 2007 Quickbird satellite image with 2-meter spatial resolution, the 2011 Google Earth image with 2-metre spatial resolution and the 2016 Google Earth image with 2-metre spatial resolution. The first research objective is to identify wetlands and to do change detection of reclamation areas.

3.1 Wetland Results 1990- 2011

The maps in Figures 3, 4 and 5 indicate that the majority of the wetlands are located in the northern part of the National Capital District (NCD – Port Moresby). These wetlands are known as permanent fresh water marshes (swamps) and waste water treatment swamps (Ramsar wetland classification, 2010).

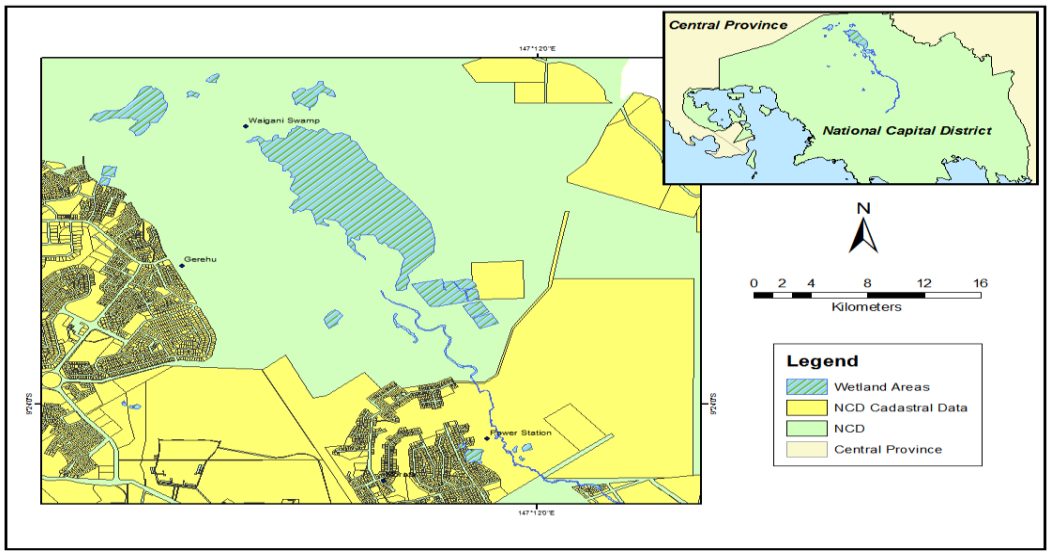

Figure 3.Identification of Wetlands-1990

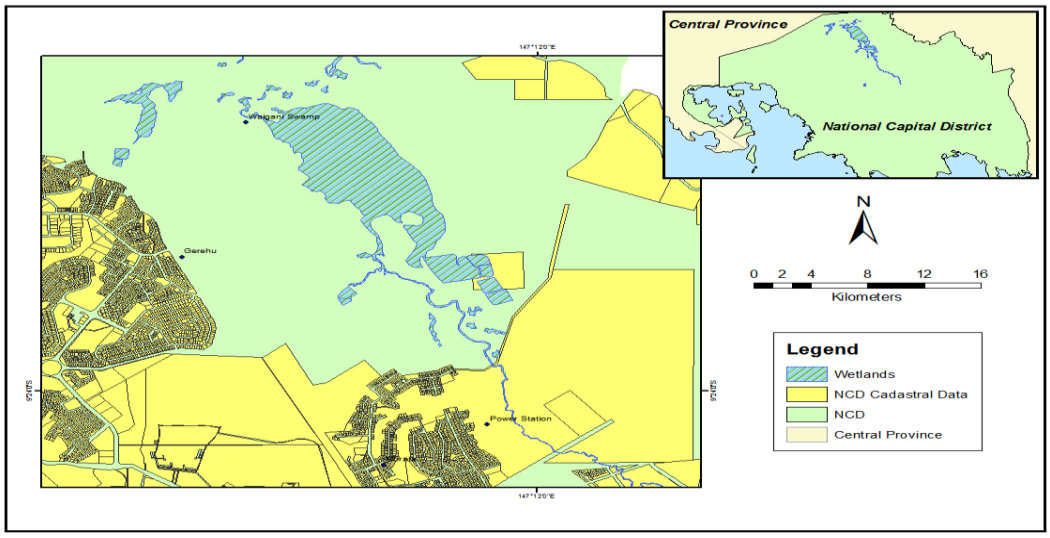

Figure 4: Identification of Wetlands -2007

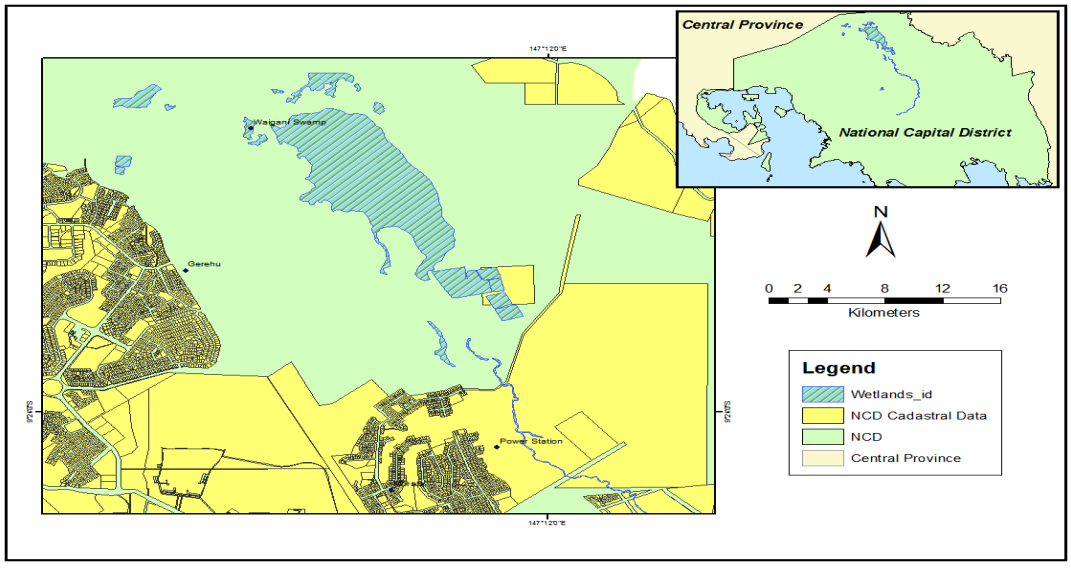

Figure 5: Identification of Wetlands -2011

The identified wetlands in the northern part of the NCD are located in Gerehu, Waigani and Morata suburbs and consist mainly of permanent or seasonal freshwater marshes, ponds, wastewater sewerages and permanent river systems. A comparative analysis of 1990 & 2007 and 2007 & 2011 wetlands are shown in Tables 2 and 3. Change in area is calculated by finding the difference between wetland areas, and then converting it into percentage.

Table 2: Change detection of wetlands 1990 & 2007

SL #	Wetland Id#	Location	Wetland Type	Change in Area m^2	Change in Percentage
1	701 & 901	Gerehu	Permanent freshwater marsh	37798	1.16
2	702 & 902	Gerehu	Seasonal freshwater marsh	18865	0.9
3	703 & 903	Waigani (Golf course)	Ponds	10660	0.51
4	704 & 904	Waigani/Morata	Permanent River	41413	-2.03
5	705 & 905	Waigani	Wastewater treatment areas	8895	-0.53
			Totals	**117 631**	

**Note: Codes beginning with 701, etc., refer to wetlands identified in 2007 and codes beginning with 901, etc., refer to wetlands identified in 1990 and 2007, while codes beginning with 1101, etc., refer to wetlands identified in 2011.*

Table 1: Change detection of wetlands 2007 & 2011

SL #	Wetland Id#	Location	Wetland Type	Change in Area m^2	Change in Percentage
1	1101 & 701	Gerehu	Permanent freshwater marsh	49109	0.43
2	1102 & 702	Gerehu	Seasonal freshwater marsh	27576	1.38
3	1103 & 703	Waigani (Golf course)	Ponds	3121	-0.13
4	1104 & 704	Waigani/Morata	Permanent River	28466	-1.27
5	1105 & 705	Waigani	Waste water treatment area	3187	0.45
			Totals	**111 459**	

**Note: Codes beginning with 701, etc., refer to wetlands identified in 2007 and codes beginning with 901, etc., refer to wetlands identified in 1990 and 2007, while codes beginning with 1101, etc., refer to wetlands identified in 2011.*

Table 2 shows the total amount of change detected between 1990 & 2007 in wetlands. The highest percentage of change is found in the permanent freshwater marshes while the river is seen to have decreased in area for 2007, mainly due to new housing estates established at the 7 mile suburb outside Jacksons International Airport. Majority of the wetland is dominated by the permanent freshwater marshes located at Gerehu and Waigani. According to Table 3, between 2007 and 2011 the amount of change detected in wetlands shows that the highest percentage of change found between the permanent freshwater marshes located at Gerehu and the waste water treatment wetlands is mainly due to the opening of two new treatment ponds. Both tables show the increase and decrease in wetlands which can be used to determine whether or not the wetlands have diminished or expanded due to factors mentioned above.

3.2 Wetland Reclamation

Figure 6 illustrates reclaimed wetlands that took place between years 1990 and 2007. In between these years, the reclamation activities have mainly occurred along the coastal region of Port Moresby especially in the Town CBD.

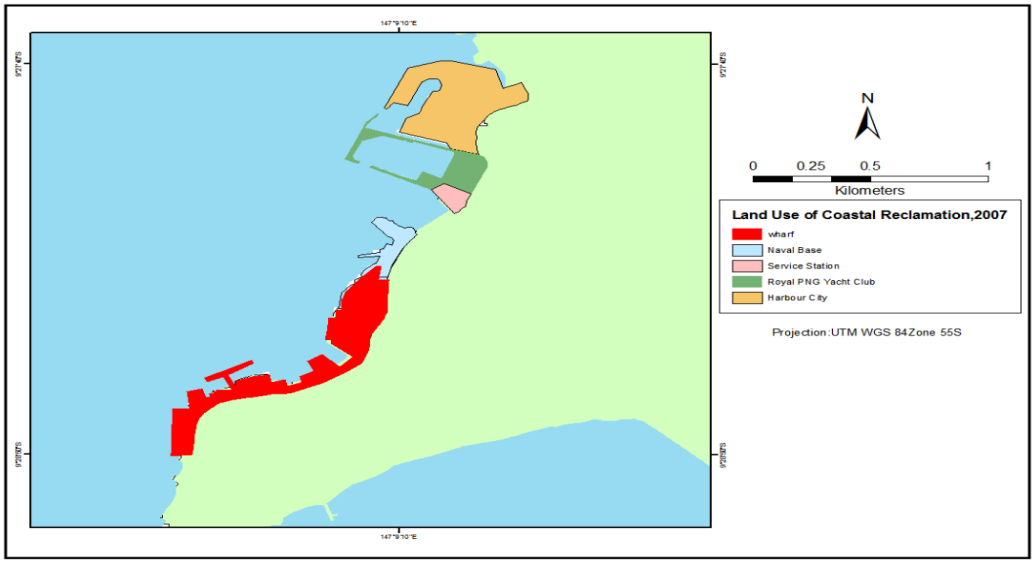

Figure 6: Reclaimed wetlands between 1990 and 2007

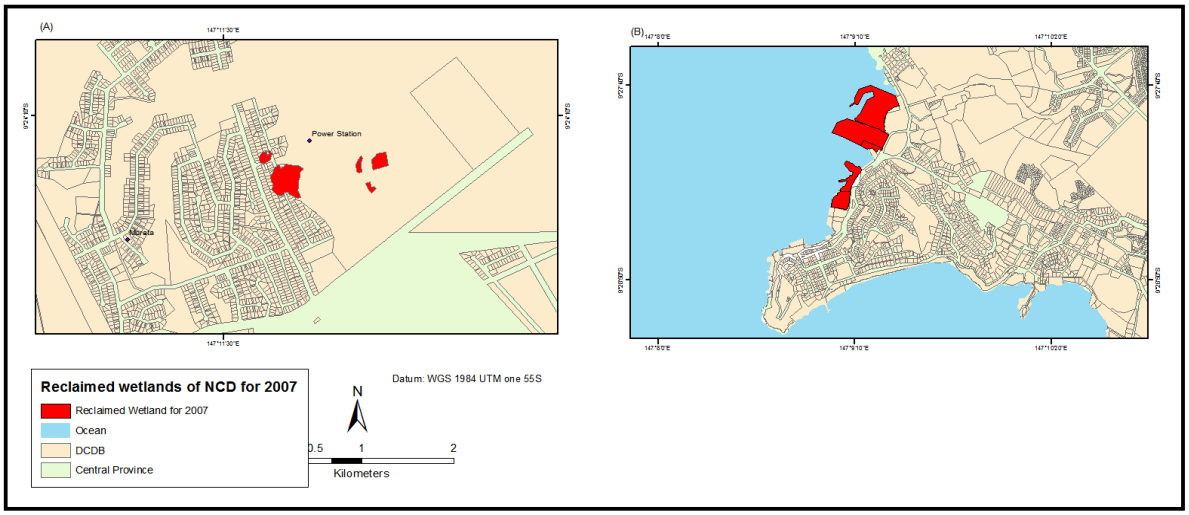

Figure 3: Reclaimed wetlands in 2007

Figure 7 shows the wetland reclamation identified for the year 2007 at the Harbor City, which was where the largest reclaimed area in Port Moresby had cropped up and now features a large shopping centre. The land use was converted into an area for expansion of the main PNG Ports wharf and naval base, service station, and recreational uses such as the yacht club and Harbor city shopping center. Table 4 shows overall view of the changes that have taken place so far.

Table 2: Amount of Reclaimed Wetlands in 2007

					2007	
SL #	**Wetland Id#**	**Location**	**Wetland Type**	**LULC Change (Current)**	**Land Area m^2**	**Percentage %**
1	706	Konedobu	Coastal	Harbor City	133549	41.942
2	707	Konedobu	Coastal	Royal Papuan Yacht Club	109265	34.315
3	708	Konedobu	Coastal	Service Station	12391	3.891
4	709	Town	Coastal	Port Moresby Main Wharf	30920	10.140
5	710	Town	Coastal	PNG Defense Force Naval Base	32288	9.711
				Total	**318413**	

Figure 8 shows that between 2007 and 2011, large scale activities of coastal reclamation took place to extend the main wharf and introduce a second new shopping centre (Waterfront) between Konedobu service station and the naval base. These new shopping/recreational areas accommodate majority of the Town and Ela Beach populations in the city and they are currently expanding. Table 5 shows information on reclaimed wetlands in year 2011.

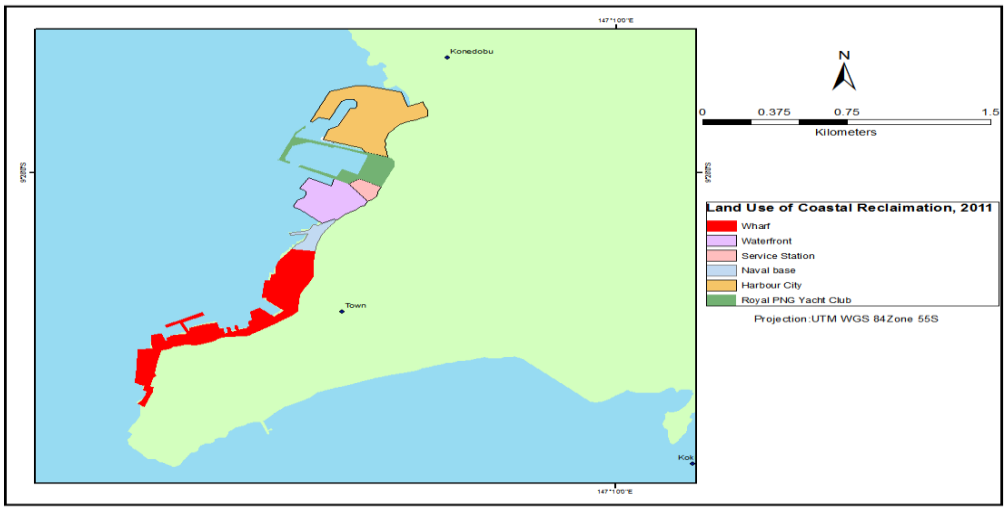

Figure 8: Reclaimed Wetlands in 2011

Table 3: Amount of Reclaimed Wetlands in 2011

			Year		2011	
SL #	**Wetland Id#**	**Location**	**Wetland Type**	**LULC Change (After)**	**Total Area m^2**	**% Change**
4	1109	Konedobu	Coastal	Waterfront Shopping Centre	76947	13.264
6	1110	Town	Coastal	Port Moresby Main Shipping Wharf	187401	26.973
				Total	**264348**	**40.2**

Figure 9 shows the coastal reclamation activity expanding drastically to accommodate for a new four-lane road around Pagahill connecting Ela Beach to the harbor side and Poreporena Highway, Konedobu. The recently concluded APEC Summit (November, 2018) is a major driving factor of the new face lift of the beach front and the development of APEC Meeting venues on reclaimed land. The map below shows the new developments in Port Moresby in 2016.

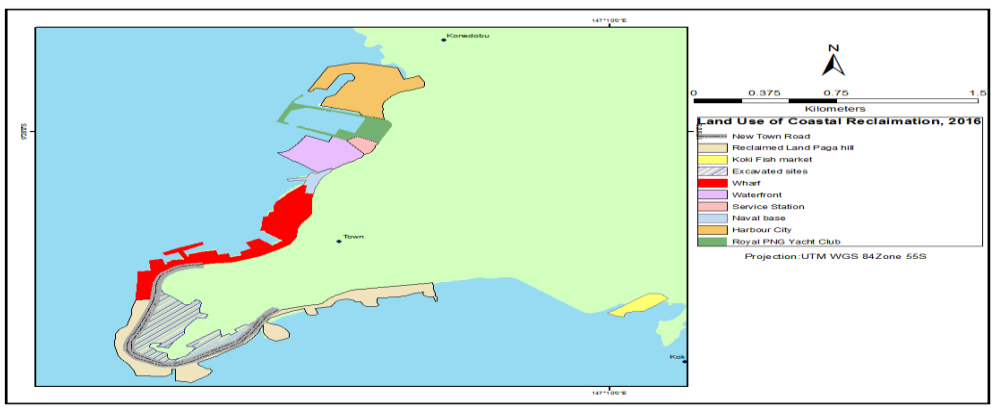

Figure 9: Reclaimed Wetlands in 2016

Table 4: Amount of reclaimed land in 2016

Year					2016
SL #	**Wetland Id#**	**Location**	**Wetland Type**	**LULC Change (After)**	**Total Area m^2**
1	1601	Pagahill to Ela Beach	Coastal	New Four lane road	239598
2	1602	Koki	Coastal	Koki Fish Market & Shopping centre	28163
				Total	**267762**

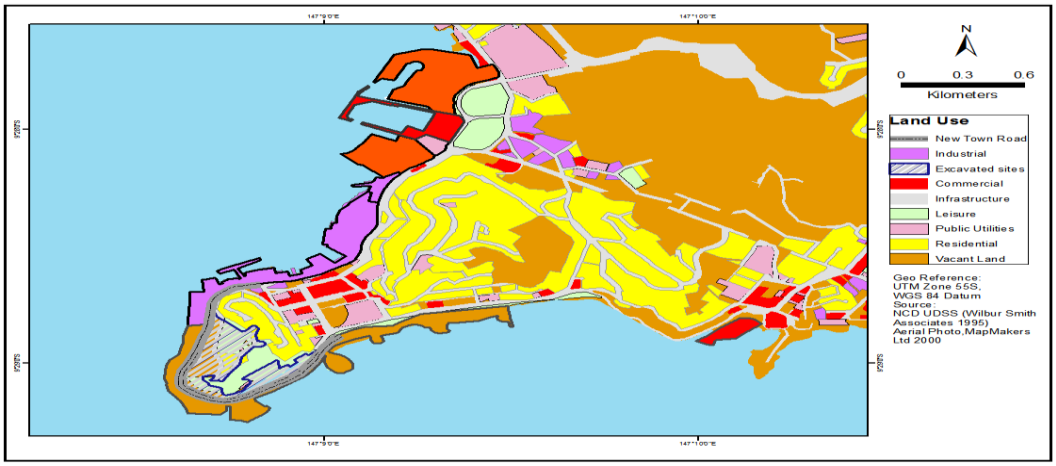

Figure 4: Updated LULC of Port Moresby, 2016

3.3 Land Use-Land Cover of Reclaimed Wetlands

The other objective of this paper is to create a land use and land cover map (LULC) of Port Moresby's newly reclaimed land as already identified in the preceding maps above.

A LULC Map of Port Moresby has already been provided by the NCDC City Council, GIS Unit, for the year 2000 and it shows the general LULC zoning. Majority of the land is vacant due to customary ownership; however, other activities such as residential (formal/informal), commercial, industrial and leisure facilities are prevalent on the reclaimed area in Town, Port Moresby.

The newly reclaimed land along Port Moresby harbor (west side) is shown in Figure 10, highlighted with a thick line weight. This land is categorized as commercial, industrial, vacant land and residential. Some of the images of land use on reclaimed wetlands are shown in Figure 11.

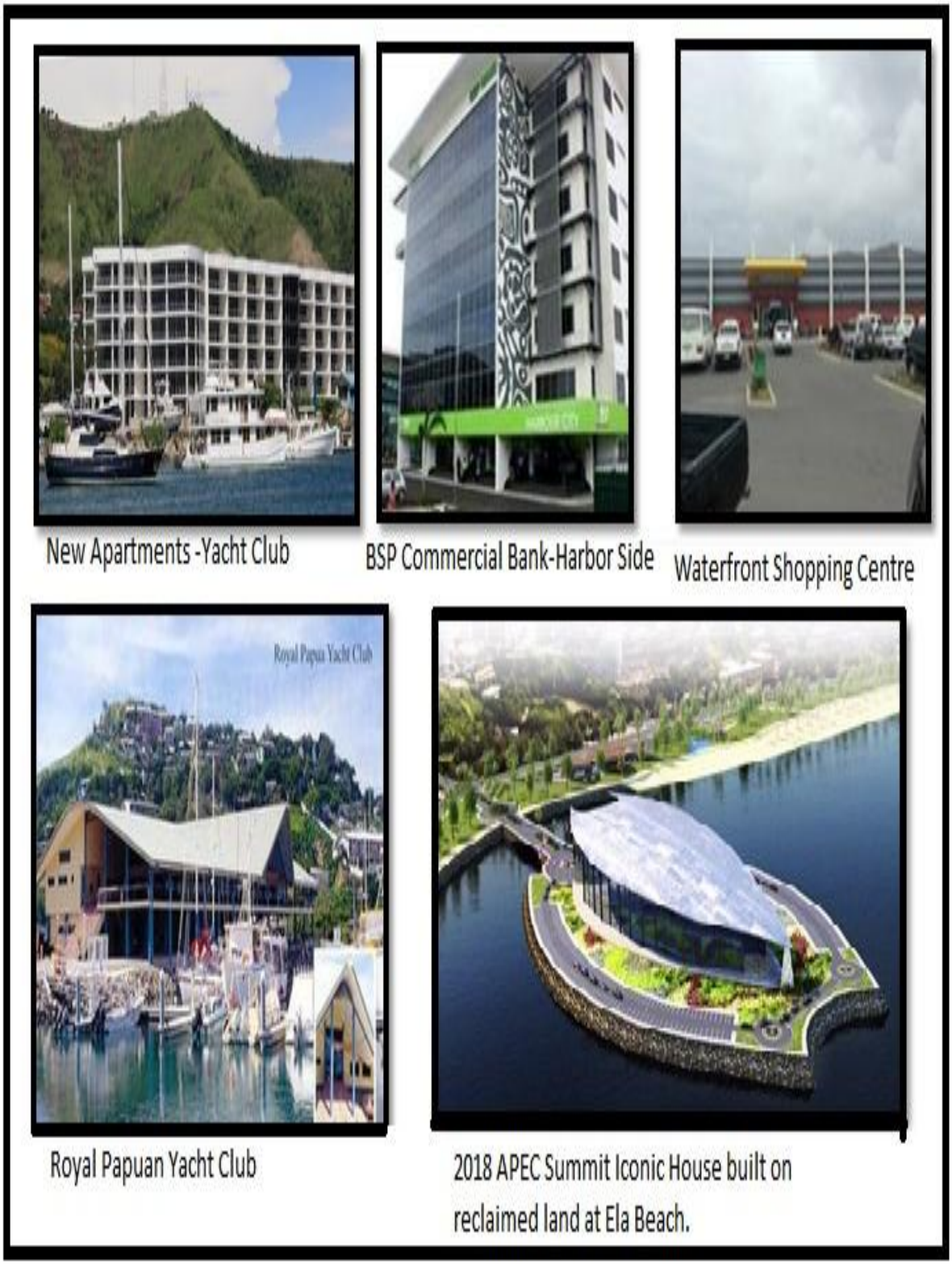

Figure 5: Images of current land use of reclaimed wetlands in Port Moresby, 2016

4. Discussion

4.1 Availability of wetlands

The results show that the number of wetlands has fluctuated between the years 1990 and 2011. Between the years 1990 & 2007 the largest change in wetlands was the permanent freshwater marshes of Gerehu

with 1.16 % change. The river and waste water treatment areas have negative percentages of change because each wetland has decreased in size due to seasonal climatic conditions that may have caused parts of the river to dry up and the wastewater treatment ponds located at Morata have been reclaimed and no longer exist, hence the decrease in size.

Between the years 2007 & 2011 there was also a fluctuation in wetland availability, the largest change in wetlands being the seasonal freshwater marshes with a percentage change of 1.38%. Seasonal freshwater marshes occur as a result of change in wet and dry seasons because Port Moresby has a tropical wet and dry climate with relatively constant temperatures throughout the year and average annual rainfall just over 1,000mm. The marshes are inconsistent in maintaining their size and shape and as a result they occur and are most dominant during the wet season and disappear or decrease during the dry season, hence the negative percentage change.

4.2 Functions of wetlands identified in the NCD

Wetland availability is vital in determining the important functions that wetlands perform in the environment. In the first section of this paper, the importance of wetlands was discussed in detail and it was explained that wetlands are beneficial to people, marine life and wildlife. They protect and improve water quality, provide habitat for biotic life and provide water storage/supply during dry periods, etc.

The permanent freshwater marshes identified in Port Moresby are very important in sustaining human life within the surrounding communities. Example of this is the large freshwater marsh located between Gerehu and Waigani. The large wetland is accessible from all surrounding areas such as 6 mile, 7 mile, 8 mile, Morata, Waigani and Gerehu. Many people living in informal settlements within these areas use the wetland waters for fishing, laundry, washing, hunting animals and gathering firewood from the bushes. The wetland has not changed significantly in shape but it has increased in small amounts of area due to the high rainfall during the wet season.

Wastewater treatment ponds are man-made wetlands located around Waigani and Gerehu; they accommodate the needs of all of Port Moresby's residential areas. Functions include biological activity and natural ecosystems and water infiltration allowing nutrients from fertilizers, septics and sewerages to dissolve wastes and be absorbed by plants and sometimes small fish. The filtration process also removes much of the pollutants in the waters or storm water and wastewater wetlands. There is sufficient number of wastewater treatment ponds located within Port Moresby that have been identified.

4.3 Purpose of wetland reclamation

Wetlands are continuously lost due to shortage of land required for uses such as agriculture, housing, industrialization and recreational needs that are hampered by the effects of urbanization in Port Moresby. The new four-lane road built around Pagahill is the largest reclamation activity seen in the city, as well as the beach front expansion. The reason for the expansion along the coastline is because the central business district (CBD), main downtown area where all businesses, commercial centres and important organizations are located, has occupied all the available vacant land for urban development purposes. A lot of high rise buildings are constructed because there is not enough space for horizontal construction and so many buildings are built vertically (high rise). As downtown still remains the CBD in the face of shortage of vacant land in the vicinity, many international corporations and wealthy businesses still choose to remain within the CBD and as a result construct their business houses on reclaimed coastal lands.

4.4 Reclaimed wetlands and the LULC

The coastal reclamation has led to an increase in land space, which allows many organizations to establish themselves on the new land provided. Between 1990 & 2007 Harbor City was constructed at Konedobu (approximately in 2006) where the shopping centre or outlet was based (formally known as

Andersons Foodworld that was later sold out to Stop N Shop). A 5.5% change in area was obtained by our analysis. Then between 2007 and 2011, waterfront shopping mall was constructed (approx. in 2010) between the Defence Force Naval Base and the Konedobu service station, while 13.3% of the coastal area was reclaimed. The second largest reclamation was done along the main wharf section for accommodating container yard storage and large equipment and machinery storage and also for large shipping vessels to the port; a 26.9% change was detected. The largest reclamation of land was done in 2016; a new four-lane road was constructed around the Pagahill consuming a land area of 239,598m^2.

4.5 Change detection

The results show that between 1990 & 2007 the change detected for wetland reclamation was at Gerehu where the permanent freshwater marsh wetland was reclaimed for development of a new residential area; the same was done for the wastewater treatment ponds at Waigani. The next set of results (Tables 7 and 8) show the change detection of newly reclaimed wetlands between the years 2007 & 2016. As mentioned previously the reclamation has occurred along the entire western coastline. In 2007 total reclaimed land area was 318 413 m^2 and in 2011 it was 580 131 m^2 with a massive increase of 45.11 %.

Table 7: Change detected for 2007 reclaimed wetlands

***note area unit m^2**					**1990**		**2007**	
SL #	**Wetland Id#**	**Location**	**Wetland Type**	**LULC Change (After reclaimed)**	**Total Area**	**% Change**	**Total Area**	**% Change**
1	701	Gerehu	Permanent Freshwater Marsh	Residential area	0.0154	1.54	0.01502	1.50
2	705	Waigani	Wastewater treatment	Residential area	0.0366	3.66	0.0379	3.79

Table 8: Change detected for 2007 & 2016 new reclaimed wetlands

Year					**2007**		**2011& 2016**	
SL	**Wetland Id#**	**Location**	**Wetland Type**	**LULC Change (After)**	**Total Area**	**%**	**Total Area**	**% Change**
1	706	Konedobu	Coastal	Harbor city	133549	41.942	165814	5.562
2	707	Konedobu	Coastal	Royal Papua Yacht Club	109265	34.315	123140	2.392
3	708	Konedobu	coastal	Service station	12391	3.891	14672	0.393
4	1109	Konedobu	Coastal	Waterfront Shopping Centre	-	-	76947	13.264
5	710	Town	Coastal	PNG Lancron Naval Base	32288	10.140	12157	-3.470
6	709	Town	Coastal	Main Shipping Wharf	30920	9.711	187401	26.973
7	1601	Pagahill	Coastal	New Four lane road	-	-	239598	41.301
	1602	Koki	Coastal	Koki Fish Market	-	-	28163.805	4.8541
				Total			**847892.8**	**91.3**

Tables 7 and 8 tabulate the key information about the year-wise change detection analysis approach. The reclaimed activity was done via coastal wetland according to the Ramsar classification of wetlands system. The Naval base shows a percentage decrease in change due to the reclamation of land for Waterfront Shopping Centre. Most of the coastal area was reclaimed for construction of the shopping

centre and for the main wharf expansion. The current LULC mainly consists of commercial land use activities such as shops and offices.

4.6 Effects of coastal wetland reclamation

The effects of wetland reclamation can be determined by knowing how much wetland has been reclaimed and the change detected. These data will provide a fair idea of the environmental, social and economic impacts wetlands have on the society. The degradation of wetlands is more threatening than loss of wetlands, because the poor conditions of wetlands accentuate vulnerability to vegetation destruction, poor water quality and quantity, disease-borne vectors, increases in water pollutants (pesticides from farms, industrial chemicals, etc.) and wildlife damage. Coastal reclamation has adverse effects on the marine environment. The effects of land reclamation depend on factors such as the size, characteristics and sensitivity of the areas and the techniques applied. Examples of these effects are: permanent loss of protected habitats, loss of endangered species, changes in coastal currents, increased noise and reduced air quality during construction phase as well as effects of benthos organisms from sand extraction, elevated fine silt concentrations and reduced coastal fishing grounds for local fishermen (OSPAR Commission, 2008).

Majority of the reclamation of wetlands was done between 2008 and 2016 along the coastline of Fairfax harbor. Nearby settlements within close vicinity of the reclaimed site include Hanuabada, Baruni, and Tatana (Motu-Koitabu villages), Konedobu and Town. These settlements have been greatly affected by the massive amounts of dust pollution in the atmosphere during the day and night because construction was ongoing 24 hours, 7 days a week. The materials transported to fill in the wetlands were obtained from blasted mountainous sites along the Poreporena freeway (Hohola, Jubilee Catholic Secondary School hill side). Large rocks/boulder materials and soil were used as infill materials as well as sand and pebbles. Reclamation activity at the Harbor City was the first to be undertaken, followed by the main wharf. Atmospheric pollution by dust was a permanent issue up until the construction was completed in 2010. Several complaints were made against Curtain Brothers by the affected residents; however, nothing was done to address the complaints. Other environmental problems faced included the destruction of coastal habitats for marine life that depended on the coastline for shelter and food such as crabs, sand fish, reef fish, sea shells, stingrays, turtles (rare species), sea weeds, mangroves etc. A lot of these species are no longer seen along the coastal waters due to the continuation of muddy / polluted waters, large rocks destroying coral life and habitats etc. Deep waters have now been transformed to shallow waters as a result of excessive filling materials being eroded by waves, which have made fishing difficult because the water level has also been affected.

Sea level rise is a major concern in the daily lives of people living over and near the coastal areas, because the Motu-Koitabuan people build their houses on stilts over the waters (stilts are approx. 8 to 10 meters long, 1.5m under bedrock/sand/mud while 6m remains under water and 1.5m remains exposed to air). They are affected by sea level rise. Coastal reclamation has a minimum impact on sea level rise on a global scale; however on a local scale such as Port Moresby the effects of sea level rise are very much evident. Another significant issue is that of Motu-Koitabuan people who sold parcels of land and sea boundary to Curtain brothers for construction. Social implications such as land owner disputes and frauds had mattered in obtaining multiple land titles causing confusion amongst the buyers and sellers of the land parcels which in turn resulted in divisions amongst families and clan members to this day. An economic impact of coastal reclamation was that many of the land owners have sold their land instead of leasing it, the effect being that land sale proceeds received by the land owners would eventually run out and they would be left with no asset. Meanwhile, the new owners (buyers) of the land would have a long-term income through such investments. A classic example of this is the shopping centers and companies that rent from the new land owners. Secondly, a lot of fishing grounds were destroyed during construction phases of reclaimed areas, which affected a lot of livelihoods that

depended mainly on marine or sea foods to sustain them. The coastal reclamation has its disadvantages and benefits. The disadvantages are as mentioned above and the advantages are that it allows for services and businesses to be relocated to more suitable locations for easy access by the population mainly because of the Poreporena freeway and minimum traffic congestion. Commercial centres such as the commercial banks ANZ and BSP and restaurants, office spaces and shopping malls are all located on the newly reclaimed wetlands. A better understanding of this can be seen in the LULC results.

5. Conclusion and Recommendations

Port Moresby being the capital of Papua New Guinea requires a wide range of information regarding the development of stages of the city. Development through a new spate of sprawling infrastructure and industrialization has been boosted over the last decade riding on the economic boom triggered by the introduction of the LNG pipeline project in the country. Everyday business plan for expanding commodity and the demand for development are high; land is a necessary resource that is in scarce supply within the city. Activities such as wetland reclamation assist developers in meeting their needs for land and hence become a very important activity. This paper is aimed at providing vital information regarding temporal changes in wetland reclamation activities that have occurred over the years in Port Moresby and as such will allow city planners to plan future developments by taking into consideration the amount of environmental degradation that will be caused and the impacts of reclamation to surrounding communities.

Finally, we recommend that further studies be carried out to update the current findings to most recent information (2018). Also it is recommended that ground truthing and GPS survey are undertaken to replicate this study and verify the findings. As a result, awareness drives can be made in the area particularly in Motu-Koitabuan villages to enable implementation of a disaster mitigation and management plan regarding sea level rise. Due to the seasonal rain and winds that occur within the tropical zone of PNG, it would be necessary to prevent king tides and strong winds from destroying houses along the coast and in the city and also from erosion of reclaimed wetland attributes, such as soil and rocks.

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