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Multi–Temporal Analysis of Land Cover Change for Disaster Risk Reduction Management in Infanta and General Nakar – Province of Quezon, Philippines

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ABSTRACT

The Philippines experiences about 20 tropical cyclones per year. Four tropical cyclones hit the Municipalities of General Nakar and Infanta between November and December 2004. These two municipalities were severely affected by landslide that rushed down the Agos River. To aid disaster risk plans and management in the future, change in land cover was determined using multi–temporal analysis. This study determined the repercussions and effects of land cover change and its possible consequences based on the disaster that happened in 2004 and the socio–economic characteristics of the area. With the purpose of assessing the changes in land cover that occurred during the periods 1994–2004 and 2004–2014, a methodology using a multifunctional Semi–Automatic Classification Plugin was used in the Quantum GIS software. Cross tabulation matrix analysis was used to distinguish those changes as a result of the transition. There was a 15.45% loss of primary forest and 15.26% gain of secondary forest and brushland from 1994–2014. Increase in built–up areas was also observed from 1994–2004 due to urban sprawl, but after the tragedy, a decrease in built–up areas was revealed due to washing away of properties in the locality. This study showed the significance of using GIS for change detection study of land cover of an area as it offers crucial information about the spatial distribution as well as land cover change.

Keywords: *climate change, land cover change, disaster risk reduction and management*

INTRODUCTION

The Philippines experiences about 20 tropical cyclones per year according to the Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA 2013), causing devastation to families, government properties, and livelihood. These damages cost millions to affected individuals. They also caused injuries and death of hundreds of people (Enz *et al*. 2009).

After each typhoon and tropical depression, affected communities always blame the rampant logging in their respective mountains as the cause of the large–scale damages. While poverty and population growth made the forests easy prey to illegal logging, some factors also contributed to the problem. Some of the identified causes of forest degradation are overexploitation, rapid population growth, and increased conversion of forest land to agricultural, residential and commercial uses (Guiang & Castillo 2006). The land use changes were pointed out as culprits of different disasters in the country.

Land use and land cover are two separate terminologies often used interchangeably (Dimyati *et al*. 1996). Land cover refers to the physical characteristics of earth's surface, captured in the distribution of vegetation, water, soil, and other physical features of the land, including those created solely by human activities (e.g. settlements). On the other hand, land use refers to the way in which land is used by humans and their habitat, usually with accent on the functional role of land for economic activities. The land use/cover pattern of a region is an outcome of natural and socio–economic factors and its utilization by man in time and space. Information on land use/cover and the possibilities for its optimal use are essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs and welfare. This information also assists in monitoring the dynamics of land use resulting from the changing demands of increasing population (Rawat & Kumar 2015).

Land use affects land cover, and changes in land cover affect land use. Changes in land cover by land use do not necessarily imply degradation of the land (Rawat & Kumar 2015). However, many shifting land use patterns driven by a variety of social causes, result in land cover changes that affect biodiversity, water and radiation budgets, trace gas emissions, and other processes that come together to affect climate and biosphere (Riebsame *et al*. 1994). Detection of land use/cover change is essential to better understand the landscape dynamics as compared with a known period with sustainable land management (Rawat & Kumar 2015). Land use/cover changes are widespread and accelerating processes, mainly driven by natural phenomena and anthropogenic activities, which in turn drive changes that would impact natural ecosystem (Ruiz–Luna

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& Berlanga–Robles 2003; Turner & Ruscher 2004). The multi–temporal analysis considers seasonal variation of the study area, which is very helpful for identification of the impacts of land use dynamic on the natural resources (Wolter *et al*. 1995). Multi –temporal analysis has been used in several studies with different approaches. A study by Sah *et al*., (2012) used multi–temporal analysis approach to classify land use to create temporal stack for nuclear incident response. Lu *et al*. (2004) used this approach for the spectral mixture analysis of Amazonian land cover change detection.

Remote Sensing (RS) was used to classify and map land cover and land use changes with different techniques and data sets. Landsat images served a great deal in the classification of different landscape components at a larger scale (Ozesmi & Bauer 2002). Landsat–TM images represented valuable and continuous records of the earth's surface during the last decades (USGS as cited by Rawat & Kumar 2015).

In the past, studies have already been conducted in the area in relation to natural disasters. Adaptation gaps and policy recommendations were made in response to extreme events in Infanta (Eugenio *et al*. 2014). A spatial distribution of rainfall–induced landslide susceptibility model was done to identify rainfall intensities that could trigger landslides in the areas of Infanta (Abucay *et al*. 2012). These studies showed the susceptibility of Infanta to calamities and the municipality's possible adaptation strategies in the future. However, high elevated areas in General Nakar where mountainous and forested areas are located have not been included in those findings. The key loss/gains of the forested areas of General Nakar are important to be considered.

Different approaches using Geographic Information System (GIS) have been used for disaster risk reduction management in the past (Hsu *et al*. 2005; Tran *et al*. 2008). These studies analyzed typhoon, flood, and landslide risks based on a single time period.

This study used multi–temporal analysis to determine significant changes in land cover change that occurred in the periods 1994–2004 and 2004–2014 in response to disaster risk reduction management. These time periods were selected in relation to the 2004 disaster that struck Quezon Province. The aim of the study was to identify key factors that changed the land cover by means of a comparison between observed changes, gains, and losses that could have possibly played a role in the 2004 disaster. The study also aimed to assess the land cover changes 10 years after the incident and how vulnerable the populated areas were to disaster risks. Multi– temporal analysis on land cover change provided essential information for planning and management and would help in the decision–making process. The result of this study would provide insights on land cover change for future disaster risk planning and studies.

METHODOLOGY

Study Area

The study area covered the Municipalities of General Nakar and Infanta in Quezon Province with a total land area of 134,375 ha and 13,010 ha, respectively (**Figure 1**). The area is located within 14°35' and 15°13' north latitude and 121°18' and 121°44' east longitude. The two municipalities were selected due to its relative location to the drainage system of the Agos River. The climate in General Nakar and Infanta falls under type II of the Modified Corona's classification system, that is, no dry season with a very pronounced maximum rain from December to February according to the Geoportal of the National Mapping and Resource Information Authority (NAMRIA). General Nakar is a mountainous area in general in comparison to Infanta, which is mostly comprised of low–lying areas. There are seven soil series identified in the two municipalities, namely: Annam Clay Loam, Antipolo Sandy Clay, Antipolo Soils (undifferentiated), Hydrosol, Mountain Soil (undifferentiated), Quiangua Silt Loam, and Umingan Loam (NAMRIA 2013).

Limitation of the Study

The study was done to assess past tragedies to generate a model predicting future disasters. In this manner, the study was limited to assessing areas prone to natural hazards in General Nakar and Infanta and due to this, validation of the output was not done due to time constraint. Flashflood and landslide of great magnitude did not occur in the past 10 years after the 2004 tragedy and thus, there was no way to validate the results other than continue to monitor the area and consider the results of this study in future planning on disaster risk management. Old satellite images from Landsat 5 could not be properly assessed for accuracy because of the changes that happened in the field.

Multi–temporal analysis for land cover change has never been used for disaster risk reduction management. Thus methodology was based on past studies on disaster risk mapping and an attempt to incorporate time series analysis to disaster risk mapping was used in this study.

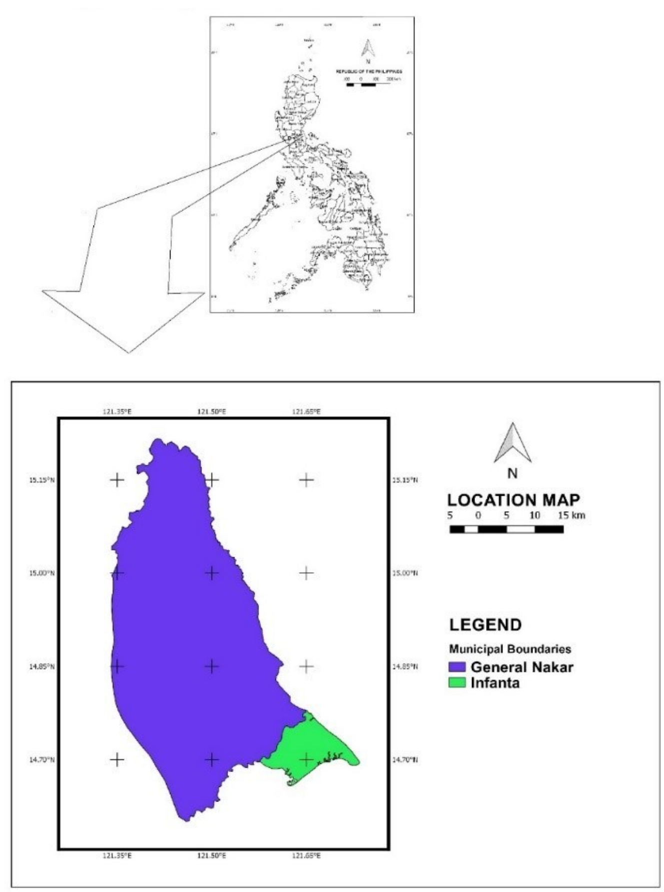

Figure 1. Location Map of the Study Area *(Source: National Mapping and Resource Information Authority).*

Data Collection

The data used in this study were gathered from different offices, agencies, and online sources. The LandSat images were taken from the United States Geological Survey's (USGS) website Earth Explorer (https://earthexplorer.usgs.gov/). The rainfall data were taken from the PAGASA office in Quezon City. Population data were taken from the office of the Philippine Statistics Authority (PSA) in Quezon City. The municipal boundaries and soil type map were acquired from NAMRIA office in Taguig City.

Data Organization and Preparation

From the SRTM–DEM files acquired from USGS and data files, geographic features were mapped individually into thematic maps. Thematic maps are useful in analyzing the spatial changes on a multi–temporal scale.

Land Cover Classification and Analysis

LandSat images of 1994, 2004, and 2014 were obtained from EarthExplorer (https://earthexplorer.usgs.gov./) using the Semi–Automated Classification Plugin (SCP) developed by Congedo (2016) in the QGIS 2.18.16 Las Palmas software. Images obtained by LandSat 5 were used over the years 1994 and 2004. Images obtained by LandSat 8 were used over the year 2014. The images obtained from USGS both have a spatial resolution of 30 m. Landsat multispectral images offer optical bands and thermal bands. In this study, optical bands were used. In downloading the image, the plugin has a pre–processing option. The *Brightness temperature in Celsius and Apply DOS1 atmospheric correction* were selected because these were the options used for the conversion of the Landsat bands from digital number to reflectance. Several satellite images were downloaded to address cloud contamination and the extent of the satellite image. Cloud masking and image mosaicking were performed to address the cloud cover and shadow issues.

Supervised classification was selected as the method of analysis. It requires the analyst to select training samples from the data that represent the themes to be classified (Jensen 1996). The training sites were geographical areas previously identified using ground–truth to represent a specific thematic class (Purkis & Klemas 2011). The supervised classification was also performed using the SCP. There are three classification algorithms available within the SCP, namely Minimum Distance, Maximum Likelihood, and Spectral Angle Mapping (SAM). In this study, the widely used Maximum Likelihood classification was adopted for the land cover classification. Maximum Likelihood algorithm is one of the most popular supervised classification methods used in most remote sensing data. The maximum likelihood classification assumes that the statistics for each class in each band are normally distributed and calculates probability that a given pixel belongs to a specific class (Jensen 1996). The first step should be selecting the training samples. In this study, the training samples were selected based on the field sampling done during March 2017 and visual interpretation techniques. Eight land cover classes were classified, namely: 1) Water, 2) Built–up, 3) Cultivated/ Agricultural, 4) Fishpond, 5) Mangrove, 6) Tree Plantation, 7) Primary Forest, and 8) Secondary Forest/Brushland.

Assessment of classification accuracy of the images was carried out to determine the quality of information derived from the data. If the classification data are to be useful in detection of change analysis, it is essential to perform accuracy assessment for individual classification (Owojori & Xie 2005). For accuracy of land cover maps obtained from the LandSat images, stratified random method was used to represent the land cover classes of the area. The accuracy assessment was carried out using 100 ROIs each for the years 1994, 2004, and 2014 based on ground truth data which was acquired through field sampling using a GPS handheld device for the reference data points, visual interpretations, and Google Earth. The error matrix measures objectively and quantitatively the goodness of fit and the quality of the results obtained. This is achieved using the kappa index proposed by Congalton and Green (2009). Kappa is a measure of agreement between predefined producer ratings and user assigned ratings (Viera & Garett 2005).

Multi–Temporal Analysis for Land Cover Change

Multi–temporal analysis was carried out to identify land cover changes that occurred between the periods 1994–2004 and 2004 –2014 in the study area. This analysis was done by overlaying LandSat images previously classified by the supervised classification method. SCP was used and the maps obtained in multi–temporal analysis were expressed in a cross–tabulation array also known as transition matrix (Pontius *et al*. 2004). This matrix identified the most important transitions that occurred in a given period. From this matrix, a percentage of the areas for each category was identified. With this information, the covers that suffered significant transitions could be distinguished, and land cover changes were identified.

Land Cover Change Analysis for Disaster Risk Reduction Management

To assess the disaster based on land cover changes, flood hazard maps generated by Project NOAH under the Department of Science and Technology (DOST) were integrated for analysis. Project NOAH is DOST's response to the call for a more accurate, integrated, and responsive disaster prevention and mitigation system, especially in high–risk areas throughout the Philippines. Rainfall history and household growth were also integrated in the analysis. With these data, the change in land cover through time was analyzed to reveal areas where detected changes had impact on natural hazards. The data also showed households susceptible to future disasters.

RESULTS AND DISCUSSIONS

Land Cover Classification

The classified land cover map of General Nakar and Infanta of years 1994, 2004, and 2014 are shown in **Figure 2**. The achieved overall classification accuracies of the classified map of 1994, 2004, and 2014 were 68%, 78%, and 90% and overall kappa statistics were 0.62, 0.74, and 0.88, respectively (Appendix Tables 1, 2, and 3). Lower accuracy on 1994 and 2004 images were generated possibly due to changes in the field where ground truth ROIs were collected. Much of the literature throughout the globe fails to state clearly whether map errors explain differences between maps from various time periods or how accuracy assessment is conducted for time points from the distant past (Aldwaik *et al*. 2015; Huang *et al.* 2012; Liu *et al*. 2014; Manandhar *et al* 2010). At some point, researchers must use the best available information to estimate change; but at some point, researchers must acknowledge that the best available information is not perfect (Enarvube & Pontius 2014).

Surface Classification Analysis

This analysis showed that the class that have reduced their cover were primary forest and water (**Table 1**). However, secondary forest/brushland increased its cover over the three time periods. This situation may be a result of rampant logging in the area claimed by some residents.

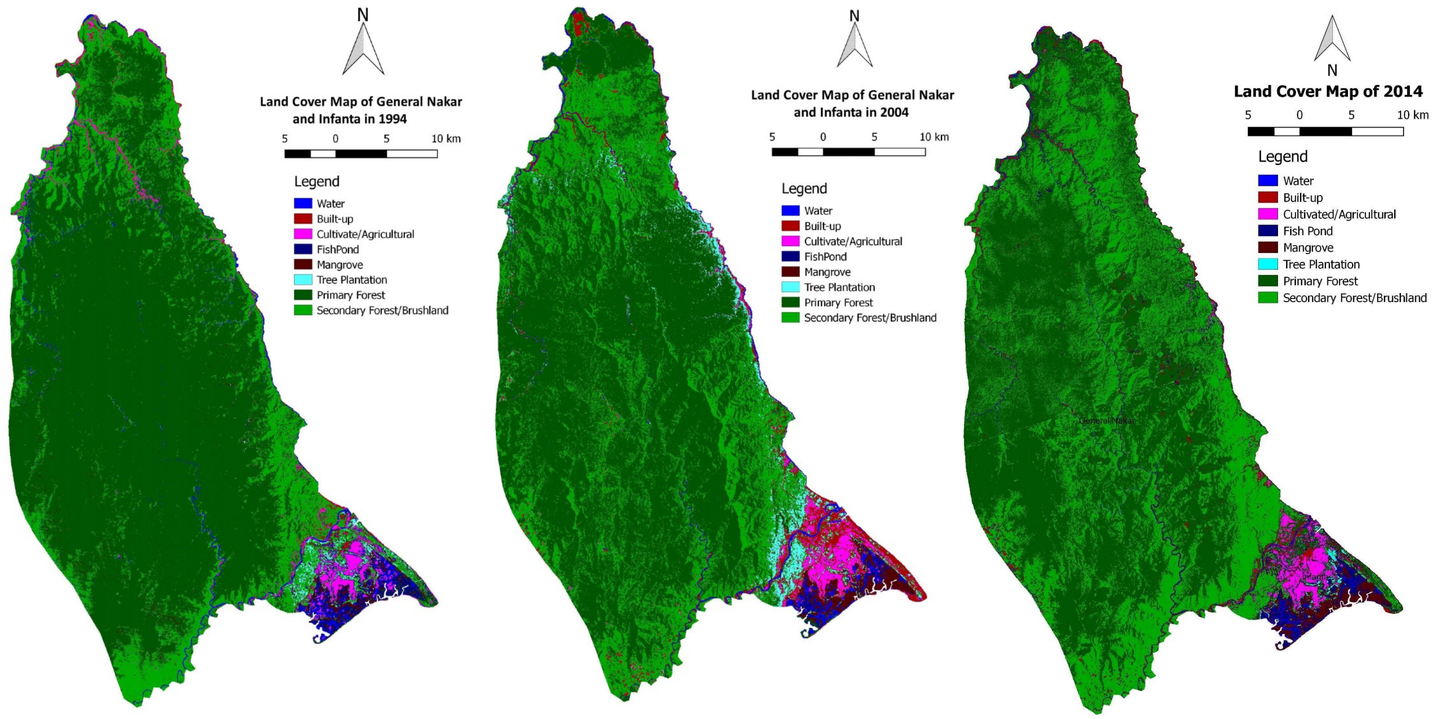

Figure 2. Classified land cover of General Nakar and Infanta: 1994, 2004, and 2014.

Table 1. Land cover classification of General Nakar and Infanta.

Class	1994		2004		2014	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Water	2585.37	1.75	1900.06	1.29	544.80	0.37
Built–up	1514.94	1.03	3821.15	2.59	2944.87	2.00
Cultivated/Agricultural	2612.68	1.77	2194.91	1.49	2234.43	1.52
FishPond	2068.12	1.40	505.14	0.34	3581.84	2.43
Mangrove	1687.93	1.15	1857.06	1.26	2101.88	1.43
Tree Plantation	996.62	0.68	504.75	0.34	330.94	0.22
Primary Forest	108887.31	73.88	102274.86	69.39	86118.67	58.43
Secondary Forest/ Brushland	27032.02	18.34	34327.06	23.29	49527.57	33.60

Image analysis showed that changes in built–up class were found near Agos River. This result demonstrated that industrialization of fishery attracted people to create communities near the river. Cultivated/agricultural areas were also shown to have decreased through the three time periods. The image analysis showed that this decrease was attributed to the built–up class. Farming is another one of the main source of income in the area. This analysis evidenced the considerable increase of urban sprawl within those 20-year period.

Land Cover Change Analysis

From the separate image analysis, land cover dynamics of General Nakar and Infanta were described for a period of 20 years. Change detection was based on multi–temporal analysis using post–classification image comparison methodology, where the same thematic classes in the overlaid map were evaluated for each period. By means of the SCP, the plugin analyzed categories that experienced changes for two periods, an initial period of 10 years (1994–2004) and a second period of another 10 years (2004–2014) (**Tables 2 and 3**). The analysis described the spatial distribution and change attributes in land cover during the different periods of the study, represented by gains and losses of areas in each class.

From 1994 to 2004, primary forest declined from 73.88% of the area to 69.39% and secondary forest/brushland increased from 18.34% to 23.29%. This means that primary forests in the 10 year span decreased and became brushlands and/or secondary forests. According to the disaster reports obtained from the Municipality of Infanta, logs rushed in with the flashflood, which was evidence of previous logging. Logging and kaingin were prominent in the area, as stated in the reports, and claimed by some of the residents. The decrease in primary forest and increase in secondary forest were still prominent from 2004–2014 (**Figure 3**), showing that 10 years after the tragedy, there were still conversions of primary forest.

Cross–tabulation matrix in both periods showed areas where no spatial changes occurred between pairs of classes (stable areas) in its main diagonal. The values outside the main diagonal indicated land covers that experienced some types of change and the direction of this change (transition between classes). This matrix quantified the area that it was maintained in its same spatial position throughout time. This array represented the most used procedure in studies of detection of land use changes (Pontius *et al*. 2004).

Table 2. Cross–tabulation matrix between 1994 and 2004.

	Classification	Water	Built–up	Cultivated/ Agricultural	Fish Pond	Mangrove	Tree Plantation	Primary Forest	Secondary Forest/ Brushland	**Total**
						2004				
1994	Water	806.09	258.04	197.12	272.96	60.35	3.97	803.87	182.97	2585.37
	Built–up	212.90	559.67	146.75	0.19	5.13	7.07	273.93	309.28	1514.94
	Cultivated/ Agricultural	333.01	468.91	1123.61	117.20	31.77	2.52	324.30	211.35	2612.68
	Fish Pond	368.95	111.39	181.81	105.77	897.73	1.65	286.71	114.10	2068.12
	Mangrove	19.08	182.20	36.61	4.36	586.12	17.92	433.66	407.99	1687.93
	Tree Plantation	6.20	208.16	11.82	0.29	84.08	105.00	62.48	518.60	996.62
	Primary Forest	56.57	489.25	94.54	3.00	155.85	74.00	88664.36	19349.73	108887.31
	Secondary Forest/ Brushland	97.25	1543.51	402.66	1.36	36.03	292.62	11425.56	13233.03	27032.02
	Total	1900.06	3821.15	2194.91	505.14	1857.06	504.75	102274.86	34327.06	

Table 3. Cross–tabulation matrix between 2004 and 2014.

	Classification	Water	Built–up	Cultivated/ Agricultural	Fish Pond	Mangrove	Tree Plantation	Primary Forest	Secondary Forest/ Brushland	**Total**
						2014				
2004	Water	252.20	582.64	49.95	766.98	66.13	1.65	149.12	31.39	1900.06
	Built–up	37.52	747.84	477.59	466.32	144.90	49.54	1369.83	527.61	3821.15
	Cultivated/ Agricultural	7.17	224.39	1350.51	187.88	62.23	4.17	296.81	61.77	2194.91
	FishPond	131.36	25.36	0.17	318.89	23.57	0.05	1.09	4.65	505.14
	Mangrove	5.30	23.23	10.97	290.90	1216.71	146.43	32.51	131.00	1857.06
	Tree Plantation	0.10	13.61	15.45	37.38	24.76	15.66	132.26	265.54	504.75
	Primary Forest	91.08	879.23	81.15	900.98	249.65	24.05	69626.36	30422.36	102274.86
	Secondary Forest/ Brushland	20.06	448.56	248.65	612.51	313.93	89.40	14510.70	18083.26	34327.06
	Total	544.80	2944.87	2234.43	3581.84	2101.88	330.94	86118.67	49527.57	

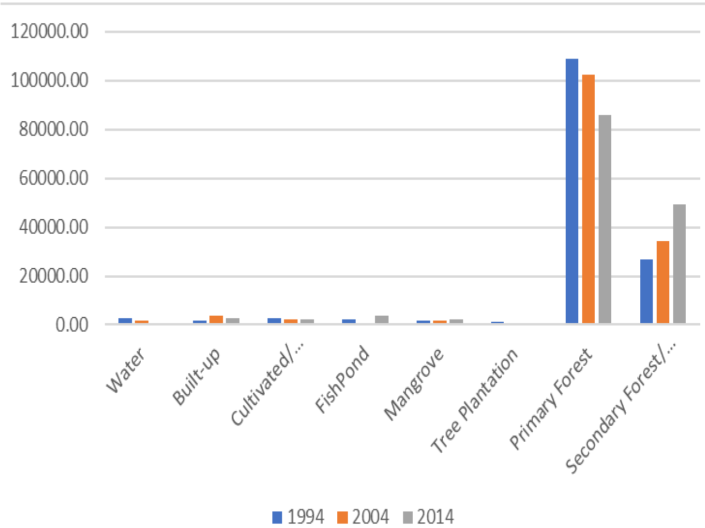

Figure 3. Graphical presentation of the land cover of General Nakar and Infanta: 1994, 2004, and 2014.

Analysis for Disaster Risk Reduction Management

Zones affected by the landslide and flashflood were identified based on the study of Orense *et al*. (2004). Assessment of its physical attributes was done to classify what made these areas susceptible to flashfloods and landslides in relation to the land cover changes that occurred. Agos River being an estuary of Polilio Strait played a huge role because the path of the flashflood and debris flow traversed through the river and affected nearby communities.

Assessments of the elevation, slope, and soil type were done and showed that the most highly affected areas were found in low lying areas in Infanta with less than 100 masl elevation and less than 5% slope near the Agos River. The rivers where the flashflood passed through were found in between high elevated areas, which were the catchment for the Agos River watershed. Areas in Barangay Magsaysay, General Nakar, where the landslide occurred have an elevation of 300–500 masl and slopes ranging from 15–25%. Four soil types were found in the affected areas namely Antipolo sandy clay, Hydrosol, Mountain soil (undifferentiated), and Quiangua silt loam. The characteristics of the physical attributes that were affected by the landslide and flashfloods were summarized in **Table 4**. Highly affected areas were categorized as areas which were affected by debris flow, flashfloods, and high flood levels. Moderately affected areas were categorized as areas which were slightly affected by debris flow and moderate flood levels. Slightly affected areas were categorized as only affected by the rainfall and experienced little to no flood. Some of the less affected areas were located near the mangrove areas. In the land cover classification, mangroves showed to be consistent in area (around 2000 ha) through the 20-year period. Mangroves are a natural protection from storm surges.

The results showed that annual rainfall was not necessarily overwhelming in 2004. Some of the monthly rainfall of other years were higher than those in 2004 but in the month of the tragedy, 938 mm of rainfall was recorded, which was one of the highest monthly rainfall in the years between 1994–2014. According to Orense *et al*. (2004), landslides occurred in areas with steep slope, forested or not and attributed the disaster to heavy rainfall saturating the slopes.

Climate change and disaster risks, together with population growth, represented a combined challenge to the achievement of sustainable development. Increasing disaster threats not only reflected the onset of events such as earthquakes or floods, but also the changing demographics and socioeconomic characteristics of the population. Population growth and distribution, especially increased population density and urbanization, heighten vulnerability to disasters (Chowdhury & Mahoux 2013).

Table 4. Summary of physical attributes of affected areas.

	Land Cover	Elevation	Slope	Soil Type	Other important notes
Highly affected areas	Built– up areas, Cultivated/ Agricultural, Water, Tree Plantation, Fishpond	0– 500 masl	up to 25%	Quiangua silt loam, Antipolo sandy clay	Most highly affected areas are low– lying areas with elevation of less than 100 masl, but the landslide occurred in Brgy. Magsaysay where elevation is between 300 – 500 masl
Moderately affected areas	Built up areas, Cultivated/ Agricultural, Tree Plantation, Fishpond, Secondary Forest/ Brushlands	0– 500 masl	up to 25%	Quiangua silt loam, Antipolo sandy clay	Mostly low– lying areas, but Brgy. Catablingan in General Nakar have some high elevation which was also affected by heavy rainfall
Slightly affected areas	Primary Forest, Secondary Forest/Brushlands, Mangrove, Tree Plantation, Fishpond	500– 900 masl, less than 100 masl	more than 25% and less than 5%	Mountain soil (undifferentiated), Hydrosol	Mostly mountainous areas. Slightly affected zones in low elevated areas were those areas far away from the Agos river

According to PSA, the lowest population among the barangays of the two municipalities in between 1995 and 2015 were Barangays Tudtunin and Minahan Norte, while the highest population was Barangay Dinahican. The growth rate of General Nakar from 1995 to 2007 was 1.37% while Infanta had a growth rate of 3.52%. This population growth directly correlated to the increase in built–up areas.

Life risks also increased in relation to the increase of population in the highly populated areas. As the municipalities experienced back in 2004, highly populated areas resulted to higher damage to properties, injuries, and casualties.

Built–up areas and flood hazard maps from Project NOAH were overlaid to show the vulnerability of communities to landslide and flashflood. Barangays with high vulnerability to flashflood and landslide were the barangays of Poblacion in General Nakar and Poblacion 1, Poblacion 38, Poblacion 39, Bantilan, and Agos–agos in Infanta. These barangays were susceptible to damages and casualty due to its high population. Barangays that were equally susceptible were Umiray in General Nakar and some nearby barangays in the Agos River. The built–up area of highly susceptible communities was 697.94 ha, which were mostly found in highly populated areas. The area of moderately susceptible communities was 227.86 ha and the area of slightly susceptible communities was 269.16 ha.

Built–up areas strongly grew from 1994 to 2004, but dramatically decreased from 2004–2014. This change was attributed to the landslide and debris flow in the area and some of the built–up areas were converted due to the large amount of soil that washed away in the two municipalities.

Disaster Prevention, Mitigation, and Preparedness

The result of this study showed that primary forest decreased while secondary forest increased, caused by logging and kaingin in the area. However, these changes have little effect on the tragedy that happened. Population increase was shown to be in the center of Infanta. As a result, these populated areas will again be at risk in the future. In the light of this study's findings, areas near Agos River are at more risk than any other areas due to its spatial orientation. As shown in Table 2, built–up areas near Agos River increased in a 10–year span, making the area susceptible to future disasters.

This study also showed the role of climate change in natural disasters. The annual rainfall of 2004 was normal, but it was misleading in the short run. Due to having low rainfall all throughout the year, nobody expected a huge amount of rainfall in a month. Rainfall in the said month was not normal. One of the causes of the disaster was the continuity of the heavy rainfall due to the four consecutive typhoons. Winnie was only a tropical depression, but it brought heavy amounts of rain in a span of three days which caused flash flood and landslides. This showed that in a larger scale, the rainfall recorded in that year could be perceived normal, but all of it happened in a span of two weeks. These typhoons and tropical depression might again happen due to the continuity of climate change.

With these findings, areas which might be safe could get narrowed down when similar typhoons and tropical depression would hit again. Barangays near Agos River were prone to the river's overflowing and in effect, may be susceptible to future flash floods. Urban sprawl is continually increasing based on the built–up areas and population data, especially in Poblacion I, Poblacion 38, and Poblacion 39 which could make them at risk for future disasters. Areas in Barangay Umiray were also susceptible to flashfloods due to its proximity to the river. Mangrove areas have been in constant hectarage, which could mean a persisting protection from storm surges. Some areas were prone to landslide because of its steep slopes and denuded vegetations. Even though primary forest reduction does not play a significant role in the 2004 tragedy, it is still alarming that until 2014, the areas of primary forest areas are still decreasing.

CONCLUSION

The study showed that SCP of QGIS can be helpful and yields promising results. This study also revealed that multi–temporal analysis on land cover change can be helpful in identifying key factors (biophysical and socio–economic) in studying possible disasters. Land cover change in the two municipalities generally decreased in primary forest and increased in secondary forest. Areas where these changes occurred exhibited similar traits like being situated in high elevation and steep slopes. High populated areas also played a role in some land cover changes due to the increase of built–up areas where population also increased. Low–lying areas with river networks were more exposed to natural disasters and more prone to overflowing due to heavy rainfall. High elevation with steep slopes were also found to be the cause of landslides. Land cover of the area was mostly primary forest, secondary forest, brushland, cultivated, and agricultural. But in the 20 years of analysis, primary forest was reduced by almost 20% from 1994 to 2014. Population growth also increased the risk of casualties because settlements were sprawled around river networks and susceptible to future disasters. The results led to the conclusion that increasing population was prominent near Agos River, which put the residents at risk. With the continuous climate change, unpredictability of the amounts of rainfall may be expected in the future. Areas around river networks should have designated areas of evacuation far from the river and identified as slightly susceptible. These findings should be subjected to validation in the future due to continuous changes in land cover and climate change.

More studies are necessary to investigate explanatory factors by which such changes are originated. Land cover is always changing, and disasters could always hit anytime so future studies are recommended to update possible causes and effects of natural disasters.

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Appendix Table 1. Error matrix for 1994 land cover classification of General Nakar and Infanta.

	REFERENCE DATA (in %)								
CLASSIFICATION	Water	Built–up	Cultivated/ Agricultural	Fish Pond	Mangrove	Tree Plantation	Primary Forest	Secondary Forest/ Brushland	Total
Water	2	0	0	0	0	0	0	0	2
Built–up	1	6	0	0	0	0	0	0	7
Cultivated/ Agricultural	0	0	13	3	1	0	0	0	17
FishPond	0	0	0	2	2	3	0	0	7
Mangrove	0	0	0	1	6	0	0	0	7
Tree Plantation	1	1	0	0	0	13	0	0	15
Primary Forest	0	0	0	0	2	1	14	10	27
Secondary Forest/ Brushland	1	4	0	1	0	0	0	12	18
Total	**5**	**11**	**13**	**7**	**11**	**17**	**14**	**22**	**100**

Appendix Table 2. Error matrix for 2004 land cover classification of General Nakar and Infanta.

	REFERENCE DATA (in %)								
CLASSIFICATION	Water	Built–up	Cultivated/ Agricultural	Fish Pond	Mangrove	Tree Plantation	Primary Forest	Secondary Forest/ Brushland	Total
Water	4	0	0	2	0	0	0	0	6
Built–up	0	6	0	0	0	1	0	0	7
Cultivated/ Agricultural	0	3	13	1	0	1	0	1	19
FishPond	0	0	0	3	0	0	0	0	3
Mangrove	0	0	0	1	6	0	0	0	7
Tree Plantation	1	2	0	0	2	14	0	1	20
Primary Forest	0	0	0	0	2	1	13	1	17
Secondary Forest/ Brushland	0	0	0	0	1	0	1	19	21
Total	**5**	**11**	**13**	**7**	**11**	**17**	**14**	**22**	**100**

Appendix Table 3. Error matrix for 2014 land cover classification of General Nakar and Infanta.

	REFERENCE DATA (in %)								
CLASSIFICATION	Water	Built–up	Cultivated/ Agricultural	Fish Pond	Mangrove	Tree Plantation	Primary Forest	Secondary Forest/ Brushland	Total
Water	5	0	0	2	0	0	0	0	7
Built–up	0	8	0	0	0	0	0	0	8
Cultivated/ Agricultural	0	3	13	0	0	0	0	0	16
FishPond	0	0	0	5	0	0	0	0	5
Mangrove	0	0	0	0	8	0	0	0	8
Tree Plantation	0	0	0	0	1	16	0	1	18
Primary Forest	0	0	0	0	0	0	14	0	14
Secondary Forest/ Brushland	0	0	0	0	2	1	0	21	24
Total	**5**	**11**	**13**	**7**	**11**	**17**	**14**	**22**	**100**