MAPPING OF FLOODED ROADS DURING RAINY DAYS IN SELECTED MUNICIPALITIES OF NUEVA ECIJA, PHILIPPINES USING AVAILABLE LIDAR DATA

R. T. Alberto[1], S. C. Serrano[2], G. B. Damian3, E. E. Camaso[3], A. R. Biagtan[3], M. F. Isip[3], K. M. Orge[3], M.J. C. Quinto[3] and R. C. Tagaca[3]

[1]College of Agriculture, Central Luzon State University, Muñoz, Nueva Ecija, 3120
Email: travert2157@gmail.com
[2]Institute for Climate change and Environmental Management, Central Luzon State University, Muñoz, Nueva Ecija, 3120
Email: scserrano@yahoo.com
[3]Phil-LiDAR 2 Project, Institute for Climate change and Environmental Management, Central Luzon State University, Muñoz, Nueva Ecija, 3120
Email: virysses_ssrs@yahoo.com.ph, elie.camaso7@gmail.com, arbiagtan@gmail.com, miguelito_isip21@yahoo.com kliif22@gmail.com, josephcalaunan@yahoo.com, tagaca_romnick@yahoo.com

KEY WORDS: LiDAR, Flooded Roads, Mitigate, OBIA

ABSTRACT: Flooding of roadways in urban areas have a devastating effect on transportation system and economic viability. Proper management of roadway systems during rainy days will enhanced safety and security of the commuters, improved traffic management, avoid damage to properties and mortality. To mitigate the impact of flooding from traveler's perspective, mapping of flooded roads using available LiDAR data during rainy days can greatly help in addressing this problems. Light Detection and Ranging (LiDAR) is a powerful remote sensing technology in the acquisition of the terrain surface information, classification and extraction which can be used to determine the elevation, width and length of existing roads. Using available LiDAR data of Sto Domingo, Talavera, Quezon and Licab Nueva Ecija, Philippines, different derivatives were generated using different software's such as Envi, ArcGIS and Lastools. The derivatives were Digital Terrain Model (DTM), Digital Surface Model (DSM), Intensity, Number of Returns, RGB bands, HSV and Green Red Vegetation index (GRVI). To extract the road classes, the derivatives were loaded to Ecognition Developer to perform Object Based Images Analysis (OBIA). The extracted road class was exported into shapefile and loaded to ArcGIS and overlaid using flood susceptibility map of the Philippines to determine the flooded roads during heavy rains. Out of 733.59 km road length of the study area, 233.85 km were found to be exposed to flooding during heavy rains. The municipalities of Talavera and Quezon have most of its roads affected by flooding during rainy days with road length of 63.69 km and 63.53 km, respectively, while the municipality of Sto Domingo have its 39.05 km road affected. With these results, motorists and the policy makers can be forewarned and think of alternative routes for the commuters and for policy makers in planning for future road rehabilitation and construction.

1. INTRODUCTION:

Flooding is quick, usually impacting a roadway within hours of the rain, giving few chances for a warning message to reach each and every motorist (Vaisala, 2016). Flooded road may interrupts the transport system that gave bad impacts to the commuters and emergency services such as ambulances, police and other services for safety purposes. In the recent years, the province of Nueva Ecija suffered the worst flooding brought by different typhoons that affect not only the transportation systems but all the major livelihood of the Province. Mapping of flooded roads during heavy rain using available LiDAR data will help to mitigate the impact of flooding from a traveler perspective as well as the delays and danger it imposes to the travelers.

LiDAR, which stands for Light Detection and Ranging, is a remote sensing method that uses light in the form of a pulsed laser to measure ranges to the Earth. These light pulses combined with other data recorded by the airborne system generate precise, three-dimensional information about the shape of the Earth and its surface characteristics (NOAA, 2016). Extraction of Road from LiDAR data is very challenging issue and has been approached in many different ways by photogrammetric and digital image processor (Narwade and Musande, 2014). Remote sensing algorithm such as Object Bases Image Analysis using Support Vector Machine (SVM) allows the incorporation of different properties such as spectral, geometric and textural properties for image classification (Phil-LiDAR 2, 2014). Thus, this application can be used to map the different land cover features especially the roadways for specific purposes.

2. OBJECTIVES:

The objective of the study is to generate map of flooded roads during rainy days in selected municipalities of Nueva Ecija Philippines using available LiDAR data

3. MATERIALS AND METHODS

3.1 Location of the study

The Municipalities of Licab, Quezon, Santo Domingo and Talavera, Nueva Ecija, Philippines were the study areas for generation of flooded road map during heavy rain (Figure 1). The four Municipalities has a total land area of 329.71 square kilometer, 148.63 square kilometer of which is highly susceptible to flooding (Lacadin, 2006). The total length of road networks of four Municipalities is 733.57 km.

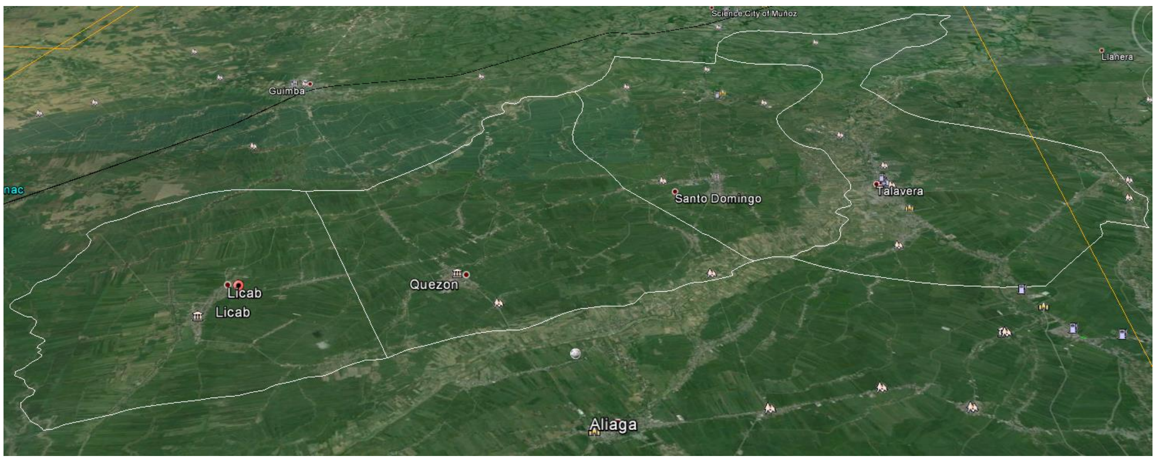


Figure 1. The location of the study

3.2 Datasets and Software Used

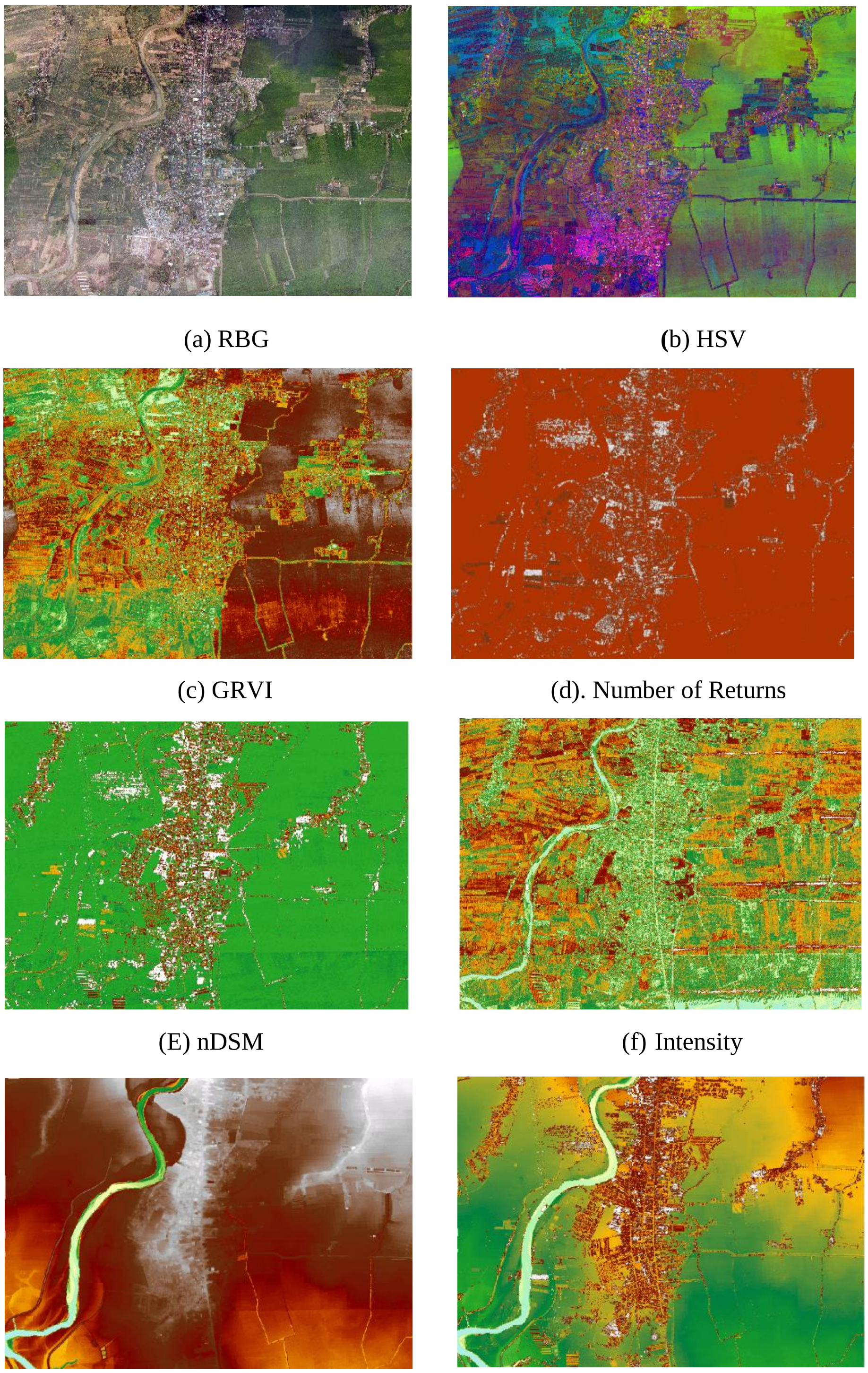
The available datasets used in the study were LiDAR flight strips from Disaster Risk Exposure and Assessment for Mitigation - Data Acquisition Component (DREAM-DAC). The LiDAR flight are PAM3H acquired last April, 28, 2014, PAM3I acquired last July 11, 2013, Pam3J acquired last June 20, 2013, Pam3K and NE1009P acquired last June 24, 2013 and July 02, 2014, respectively. Different software were used to process the LiDAR data and Orthophoto image to produced road flood map. The software's used in the study were Lastools which is used to produce Digital Terrain Model (DTM), Digital Surface Model (DSM), Intensity and Number of returns, while Envi was used to produce the Red, Green Blue (RGB) Layers, Green Red Vegetation Index (GRVI), Hue Saturation and Value (HSV), the ArcGIS on the other hand was used to produced normalized DSM (nDSM), Curvature and the Ecognition developer to extract the road network shapefile. Table 1 shows the different derivatives used in the study to produced road flood map (Phil-LiDAR 2, 2014).

Table 1. List of derivatives for road extraction

Data Sources	Derivatives	Description
LiDAR	Intensity	Created from the whole intensity spectrum of LiDAR point cloud. Generally, Objects with high reflectivity, have higher intensity than dark objects
LiDAR	Number of Returns	Created from number of return of LiDAR point clouds, useful in separating buildings and
LiDAR	Curvature	Second derivative of a surface or slope of the slope
LiDAR	nDSM	DTM subtracted from DSM to obtain the height of the objects above the ground
Orthophoto	RGB	Original bands of the Orthophoto, show spectral properties of features
Orthophoto	HSV	Transformation applied to the original Orthophoto image in the HSV color space.
Orthophoto	GRVI	Useful for identifying vegetation and non-vegetation features

3.3 Derivatives

Figure 2 shows the sample derivatives of flight PAM3I block 1, the area of sample derivative is 11.37 square kilometer.



(a) RBG (b) HSV

(c) GRVI (d). Number of Returns

z

(E) nDSM (f) Intensity

(g) DTM (h) DSM

Figure 2. Different derivatives used to generate road flood map (a) RBG, (b) HSV, (c) GRVI, (d) Number of Returns, (e) nDSM, (f) Intensity, (g) DTM and (h) DSM

3.4 Conceptual Frameworks and Methodology

The methodology in this study includes three processes: the Pre-processing, Data Processing and Post-Processing. In Pre-Processing, the LiDAR data and Orthophoto images were utilized to generate different derivatives to use in data processing. Also, training points for roads and not road class were selected using ArcGIS and to be used in processing of data. In data processing, all derivatives were loaded in Ecognition developer for Object Based Image Analysis using Support Vector Machine (SVM). The support vector machine is a supervised learning method that generates input-output mapping functions from a set of labeled training data (Wang, 2005). Lastly, in post processing, using spatial analysis the extracted road together with flood susceptibility map of the Philippines were loaded in ArcGIS to determine road length affected when heavy rain occurs. Figure 3 shows the conceptual framework of the study.

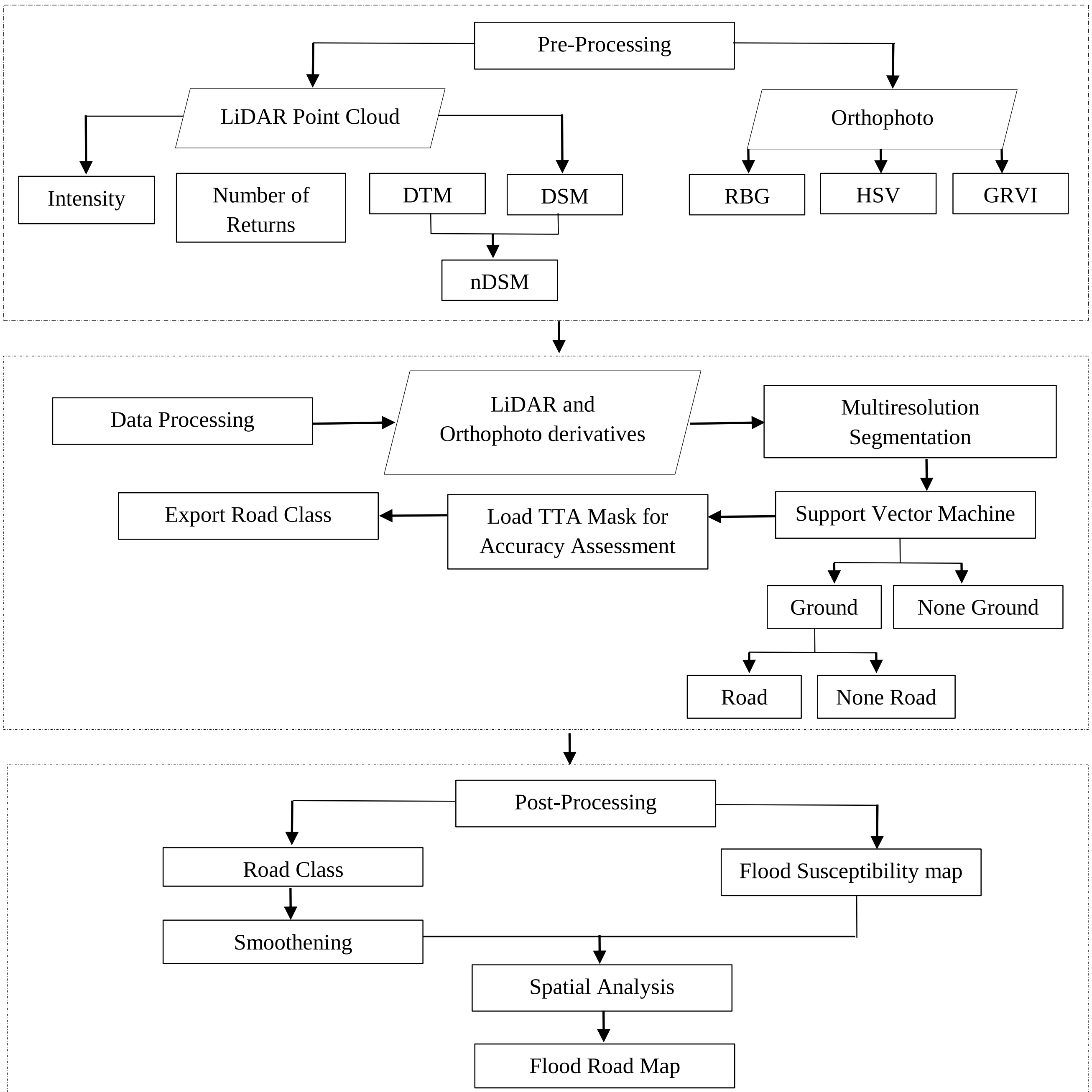


Figure 3. The conceptual framework of the study

4. RESULTS AND DISCUSSION

4.1 Licab Nueva Ecija

Licab is situated at 15.55° North latitude, 120.76° East longitude and 23 meters elevation above the sea level with a total area of 67.37 square kilometers. During rainy seasons, Barangays in the northern portion of the municipality is flood free barangays while the other five barangays are mostly flooded (Wikipedia). Figure 4 shows the road networks flood susceptibility map of Licab, Nueva Ecija. The figure shows that the western part of the Municipality were highly susceptible to flooding covering 55.97% of road networks. The road networks of six Barangays were affected by flooding during heavy rains such as Tabing Ilog, Villarosa, San Juan, Linao, Poblacion Norte and Poblacion Sur. The Average accuracy and *kappa* coefficient of the generated map were 96.78% and 0.9357, respectively (Figure 2).

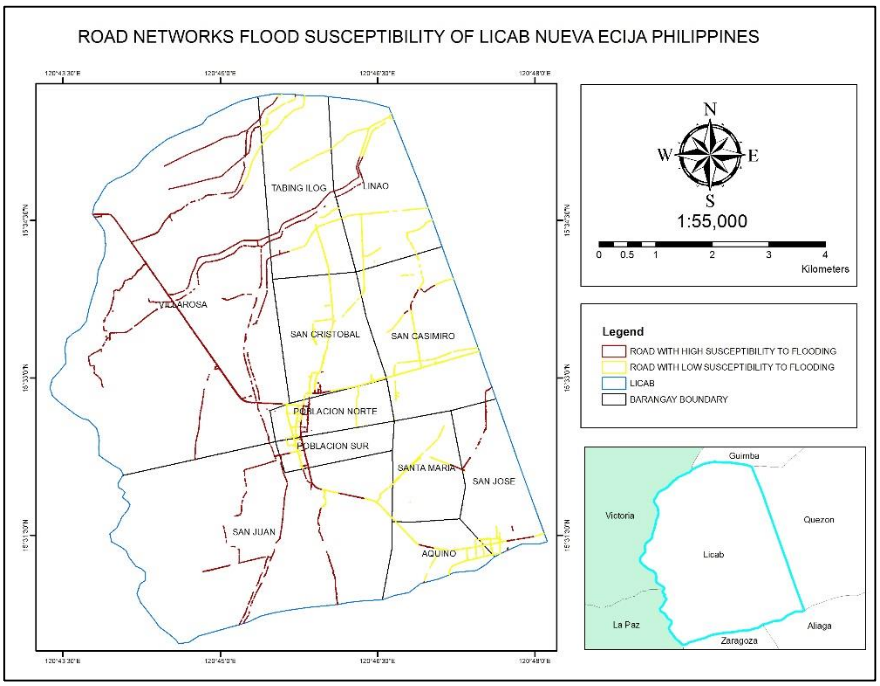
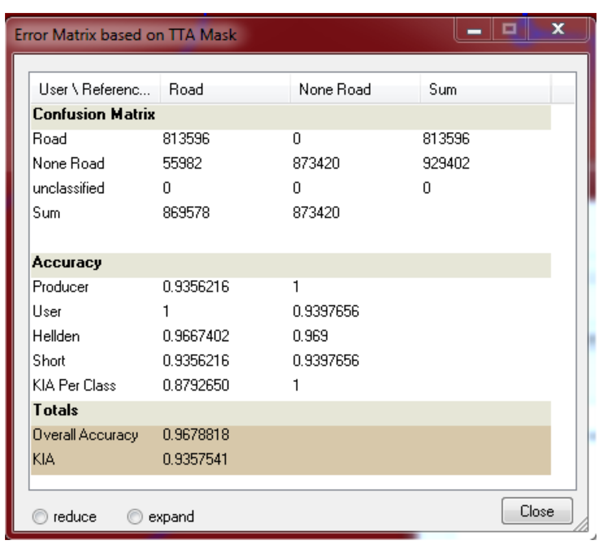


Figure 4. The road networks flood susceptibility map of Licab, Nueva Ecija


Error Matrix based on TTA Mask

User \ Referenc...	Road	None Road	Sum
Confusion Matrix			
Road	813596	0	813596
None Road	55982	873420	929402
unclassified	0	0	0
Sum	869578	873420	
Accuracy			
Producer	0.9356216	1	
User	1	0.9397656	
Hellden	0.9667402	0.969	
Short	0.9356216	0.9397656	
KIA Per Class	0.8792650	1	
Totals			
Overall Accuracy	0.9678818		
KIA	0.9357541		

reduce expand Close

Figure 5. Accuracy assessment of the produced map

4.2 Quezon Nueva Ecija

Quezon is a fourth class municipality in the province of Nueva Ecija, Philippines, located at 15.33° North latitude, 120.49° East longitude with a total land area of 68.53 square kilometers (Wikipedia). Figure 5 shows the road networks flood susceptibility map of Quezon, Nueva Ecija. The figure revealed that the portion of road networks of 10 out of 16 Barangays were highly susceptible to flooding during rainy days, and these are Santa Rita, Bertese, Ilog Baliwag, San Alejandro, San Andres 1, San Andres II, Pulong Bahay, Sta Clara, Sto Cristo and San Juan. The Average accuracy and *kappa* coefficient of the produced map were 92.26% and 0.845, respectively (Figure 6).

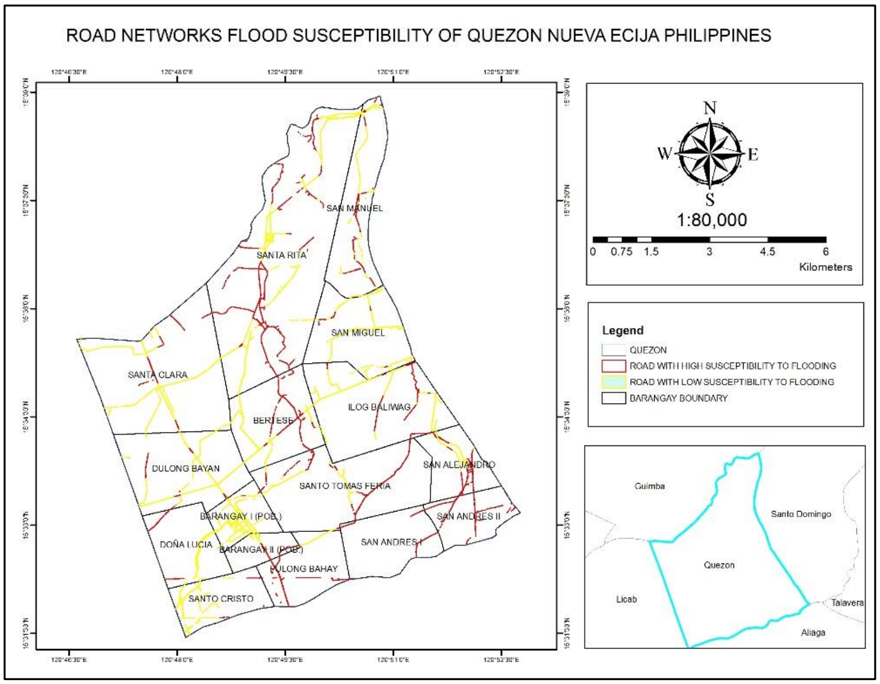
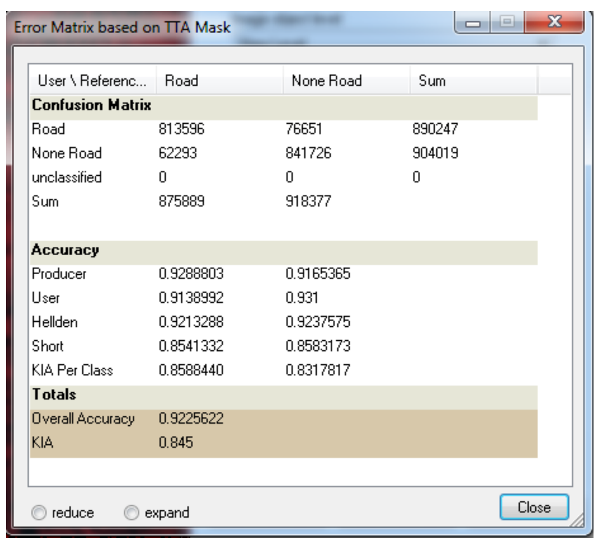


Figure 5. The road networks flood susceptibility map of Quezon, Nueva Ecija



Error Matrix based on TTA Mask

User \ Referenc...	Road	None Road	Sum
Confusion Matrix			
Road	813596	76651	890247
None Road	62293	841726	904019
unclassified	0	0	0
Sum	875889	918377	
Accuracy			
Producer	0.9288803	0.9165365	
User	0.9138992	0.931	
Hellden	0.9213288	0.9237575	
Short	0.8541332	0.8583173	
KIA Per Class	0.8588440	0.8317817	
Totals			
Overall Accuracy	0.9225622		
KIA	0.845		

reduce expand Close

Figure 6. Accuracy assessment of the produced map of Quezon, Nueva Ecija

4.3 Santo Domingo Nueva Ecija

Santo Domingo or Sto. Domingo is a third class municipality in the province of Nueva Ecija located at 15.35° North latitude, 120.52° East longitude with a total land area of 74.88 square kilometers (Wikipedia). Figure 7 shows the road networks flood susceptibility map of Santo Domingo, Nueva Ecija. The figure revealed that Barangays Dolores, San Agustin, Concepcion, Malaya, Malasin, Buasao and some portion of Santo Rosario, Baloc, Malayantoc and Sagaba were high susceptible to flooding during heavy rain. Figure 8 shows the average accuracy and *kappa* coefficient of the produced map with the value of 92.42% and 0.8481 respectively.

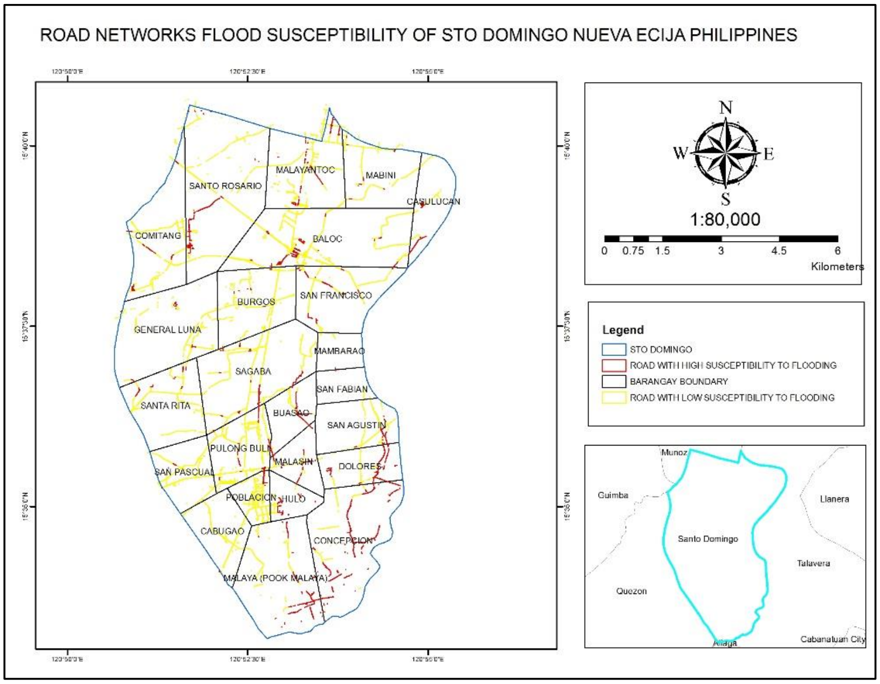
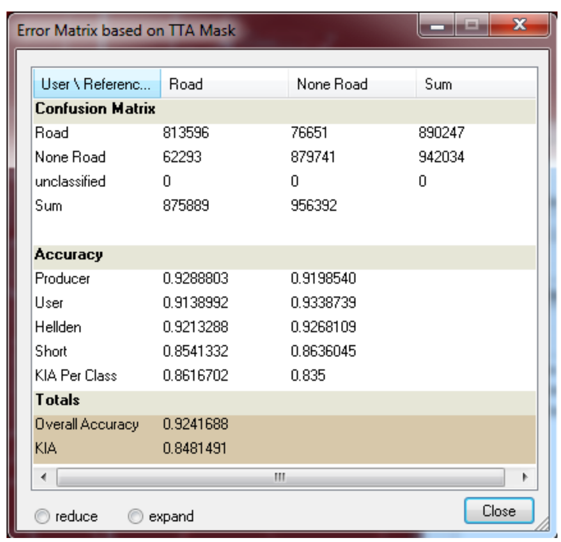


Figure 7. The road networks flood susceptibility map of Santo Domingo, Nueva Ecija



Error Matrix based on TTA Mask

User \ Referenc...	Road	None Road	Sum
Confusion Matrix			
Road	813596	76651	890247
None Road	62293	879741	942034
unclassified	0	0	0
Sum	875889	956392	
Accuracy			
Producer	0.9288803	0.9198540	
User	0.9138992	0.9338739	
Hellden	0.9213288	0.9268109	
Short	0.8541332	0.8636045	
KIA Per Class	0.8616702	0.835	
Totals			
Overall Accuracy	0.9241688		
KIA	0.8481491		

reduce expand Close

Figure 8. Accuracy assessment of the produced map of Santo Domingo, Nueva Ecija

4.4 Talavera Nueva Ecija

Talavera is a first class municipality in the province of Nueva Ecija, Philippines located at 15.35° North latitude, 120.55° East longitude with a total land area of 74.88 square kilometers (Wikipedia). Figure 9 shows the road networks flood susceptibility map of Talavera, Nueva Ecija. The Figure shows that most of Barangays has portion of road with high susceptibility to flooding. The most affected Barangays were San Miguel na Munti, Baluga, Dinarayat, La Torre, Pobalcion Sur, Pag Asa, Dimasalang, Bugtong na Buli, Bulac and Basang hamog. The Average accuracy and *kappa* coefficient of the produced map were 97.90% and 0.90, respectively (Figure 10).

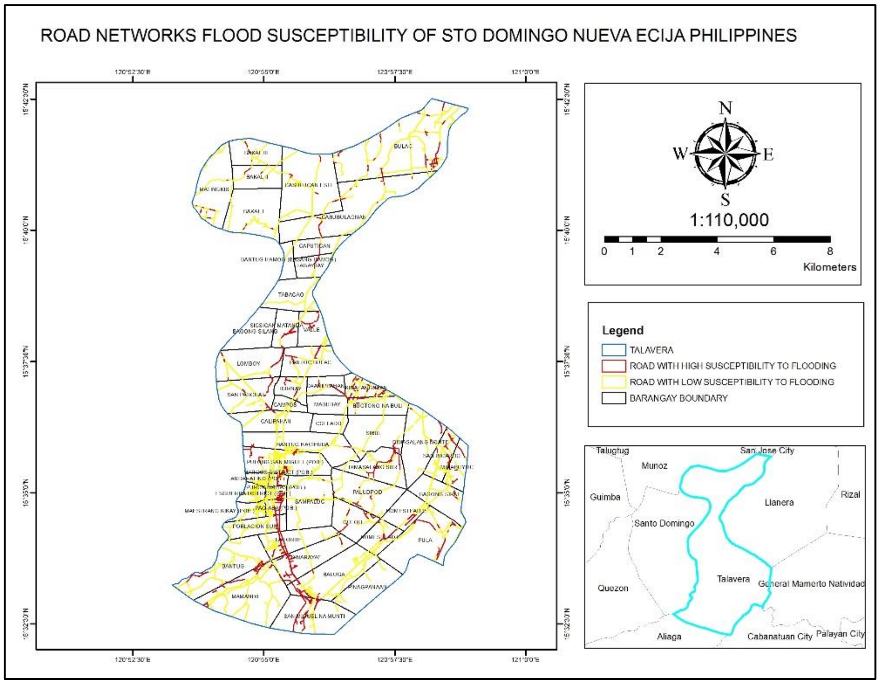


Figure 9. The road networks flood susceptibility map of Talavera, Nueva Ecija

Error Matrix based on TTA Mask

User \ Referenc...	Road	None Road	Sum
Confusion Matrix			
Road	871782	6177	877959
None Road	14854	108902	123756
unclassified	0	0	0
Sum	886636	115079	
Accuracy			
Producer	0.9832468	0.9463238	
User	0.993	0.88	
Hellden	0.988	0.912	
Short	0.9764441	0.8381397	
KIA Per Class	0.8643949	0.9387577	
Totals			
Overall Accuracy	0.979		
KIA	0.9		

reduce expand Close

Figure 10. Accuracy assessment of the produced map of Talavera, Nueva Ecija

4.5 Summary

Table 2 shows the road length of selected municipalities of Nueva Ecija, Philippines with high susceptibility to flooding. Results shows that the municipality of Licab has the highest percentage of roads affected during heavy rains, 55.97% or 57.58 kilometers out of 102.88 kilometer road length was highly susceptible to flooding, followed by Quezon with 38.81 percent or 63.53 kilometers out of 163.68 kilometer of road length. The Municipalities of Talavera and Sto Domingo has the lowest percentage of roads with high susceptibility to flooding. The percentage road length affected in Talavera and Sto Domingo were 22.71% or 63.69 kilometer out of 280.44 kilometer and 20.92% or 39.05 kilometer out of 186.59 kilometer, respectively.

Table 2. The road length with high susceptibility to flooding of selected municipalities of Nueva Ecija, Philippines

MUNICIPALITIES	ROAD LENGTH	ROAD LENGTH WITH HIGH SUSCEPTIBILITY TO FLOODING	PERCENT ROAD AFFECTED (%)
TALAVERA	280.44	63.69	22.71
QUEZON	163.68	63.53	38.81
LICAB	102.88	57.58	55.97
STO DOMINGO	186.59	39.05	20.92
TOTAL	**733.59**	**223.85**	**30.51**

Figure 11 shows the road networks flood susceptibility of selected municipalities of Nueva Ecija, Philippines, the total Road length of the study is 733.59 kilometers of which 223.85 kilometers were highly susceptible to flooding or equivalent to 30.51%.

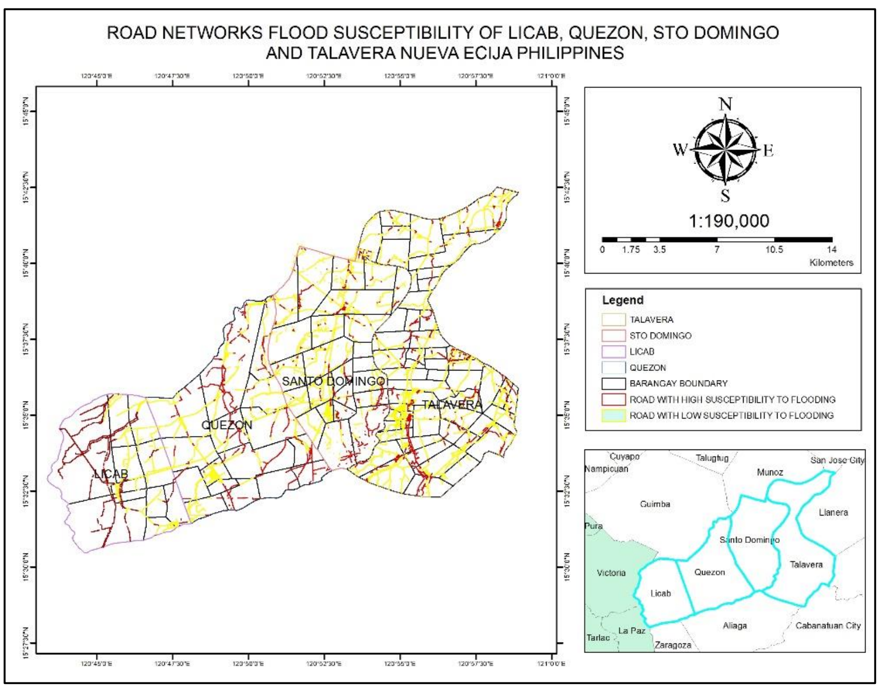


Figure 11. The road network flood susceptibility map of selected municipalities of Nueva Ecija, Philippines

5. CONCLUSIONS

Object-based Image Analysis approach using Support Vector machine was prove to be very effective for extracting road networks based on the available LIDAR point clouds and Orthophoto image. The results showed that the average accuracy and *kappa* coefficient of the generated road flooded map were 94.84 and 0.8822%, respectively. Also, OBIA in eCognition gives friendly manner which allows the correction of classification results to improve the accuracy of generated maps.

In this study, the combination of simple spatial analysis and Object Based Image Analysis was suited in determining the road networks with high susceptibility to flooding.

6. ACKNOWLEDGEMENT

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