Hydrologic Dataset Extraction Around the Downstream Portion of Cabulig Watershed using Lidar Derived Digital Elevation Model (DEM)

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ABSTRACT

Digital Elevation Models (DEMs) processed through the combined application of Remote Sensing (RS) and Geographic Information Systems (GIS) technologies were the most critical datasets to the success of surface hydrologic modelling applications. This study aims to extract the hydrologic features like drainage line, inland wetlands and irrigations of Cabulig watershed using available LiDAR datasets. WhiteboxGAT and QuantumGIS were used to extract wetlands and irrigation while ArcGIS software was used for streams. The extracted features were validated using ancillary maps and Google Earth while features that are not clear were assigned as Point of interest (POI) and were subjected for ground validation. Aside from POI, random sampling tool was used to generate points subject for field validation. The results showed that the extracted features have higher average accuracy in comparison to the data obtained from the field regardless of specific type of hydrologic features. The extracted streams network using ArcGIS showed the highest accuracy while the extracted wetland features using the combined applications of WhiteboxGAT and QuantumGIS showed relatively lower accuracy Therefore, this study was able to extract the hydrologic features of Cabulig watershed using LiDAR-derived DTMs with higher levels of accuracy compared to lower resolution DEMs.

Keywords: *Light Detection and Ranging, Water Resource Inventory, Water Resource Mapping*

INTRODUCTION

Digital Elevation Models (DEMs) are the most critical datasets to the success of surface hydrologic modelling applications (Li et al., 2013). These datasets can be used to produce critical topographic and hydrologic derivatives, such as slope, aspect and flow accumulation. It can be so important also for extracting boundaries of rivers, lakes or any other inland wetland types of water and leads to an evaluation and monitoring of water resources, flood prediction, GIS database updating, water pollution detection and measuring the amount of suspend sediment in the water (Y Zhu, 2003).

One of the products that the DEM can produce is a watershed. According to Amatya (2013), watershed is an organizing framework for the assessment of hydrologic and ecological functions and various impacts of the landscape. This is a composition mainly of three categories or types: streams, inland wetlands and irrigations. Streams or drainage network extraction from raster DEM is a necessary requirement in almost all hydrological and environmental analyses and determining surface water flow direction is a fundamental problem (Yang et al., 2010). It is also a solution for determining those wetlands and irrigation that is dependent on him.

This study aims to produce an extracted water features such as streams, irrigation and wetlands within the downstream portion of Cabulig watershed in Misamis Oriental, Philippines using RS and GIS applications based from the available LiDAR DTM/ DEM. Cabulig watershed is one of the important watersheds in the province since it supports agricultural production, recreation and domestic and industrial purposes. Hence, the results of this study could provide an updated hydrologic dataset within a portion of Cabulig watershed.

METHODOLOGY

The study was conducted in Jasaan and some parts of the Municipalities of Balingasag and Claveria, Misamis Oriental were the Cabulig river basin (RB) is situated. The area covered 78.07 square kilometers of LiDAR data as shown in Figure 1. The LiDAR covered area are geographically lying between 124.733193" E longitude 8.694586" N latitude, 124.748978" E longitude 8.627943" N latitude, 124.813697" E longitude 8.694319" N latitude, 124.847329" E longitude 8.628188" N latitude . The LiDAR dataset was acquired last August, 2013.

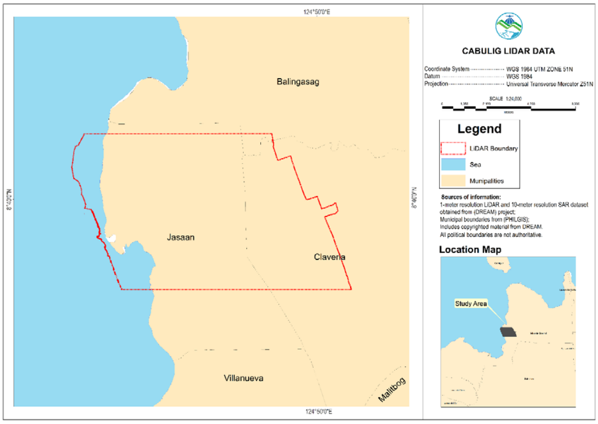

Figure 1. Area of Coverage

Figure 2 presents the overall procedural framework of hydrological features extraction from LiDAR derived DEM. WhiteboxGAT and QuantumGIS were used to extract wetlands and irrigation while ArcGIS software was used for streams. The extracted features were validated using ancillary maps and ground validation. Random sampling tool was used to generate points subject for field validation.

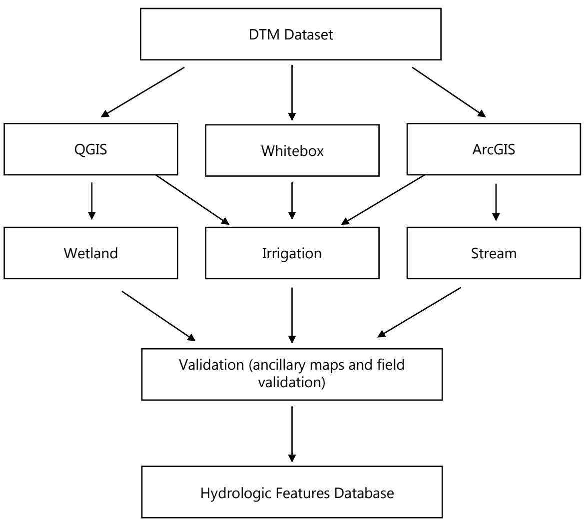

*Figure 2.*Procedural Framework

Arc Hydro uses the D8 flow direction method and allows for further post processing steps such as time series analysis of watershed data and construction of geometric flow networks using the Arc Hydro output (Nelson A.C et al., 2006). In this study, modified method of extraction used to LiDAR derived DEMs with 1 meter resolution was the major data needed in streams network extraction. The DEM was devoid of any interference such as bridges and dams in order to ensure that the flow of the streams is not disrupted. Stream network extraction and watershed delineation was performed using hydrology tools of spatial analyst of ArGIS Software. A stream network was delineated by applying a threshold value to the results of the flow accumulation tool using either the con or set null tools. Flow accumulation is the simplest form that computes the up-slope cells that flows into each cell.

The pre-processed DEM was resolved first using QGIS to undergo tiling process. The resolved DEM was re-processed in Whitebox GAT to undergo stochastic depression analysis (SDA), majority filtering, reclassification and vectorization. SDA tool was used to detect depressions that serve as a good indicator of inland wetlands while majority filtering tool was used to eliminate the noise detected. The reclassification tool was used to separate the true detected depression from those that are false and the reclassified raster was then converted to vector. In an attempt to delete false depression, objects less than 50 sq.m. as suggested by Wu et al., (2014) were eliminated. Lastly, the resulting polygon was then overlaid in Google earth satellite imagery in order to verify the detected depression.

Map Gully Depth (MGD) tool in Whitebox was used to process LiDAR derived DEMs. The processed DEM was reformatted into Saga grid files. The value of the maximum gully width in x and y-units, the minimum and maximum gully depths in z units, threshold difference from mean elevation (DFME), plan curvature threshold and smoothing parameter were specified. The reformatted DEM files were then exported into shapefiles for refinement to determine if the features were true. The resulting irrigation feature extracted from the MGD together with Digital Elevation Model (DEM) was then overlaid in the Google Earth imagery in order to digitize the irrigation features.

The extracted hydrologic features were validated in the field (except for private areas) to confirm its existence as presented in Figure 3. The validated features were marked and the specific attributes per feature were determined for filtering purposes using weighted disproportionate stratified random sampling tool. This process shall be done per feature type in order to calculate the thematic accuracy based from the result of validation process.

Figure 3. Field Validation Showing the Validated Wetland, Irrigation, and Stream

RESULTS AND DISCUSSION

Streams

The results of the methods used in extracting stream using LiDAR derived DEM was able to extract 11,963.5 m length of the Cabulig River including the 17 tributaries within the Jasaan Municipality. The method also showed high degree of accuracy of 90% in which 120 extracted line features out of 141 for streams needed refinement after field validation. This result is higher compared to the method used by Nelson A.C et al., (2006) which only showed 64% accuracy. These newly extracted streams features will be useful for updating the stream resource map in the study area. The generated stream network will also serve as baseline information for local government units in planning for future infrastructure projects like dams needed for irrigation that will support agricultural productivity in the study area. Figure 4 shows a sample of the aerial feature of stream after field validation.

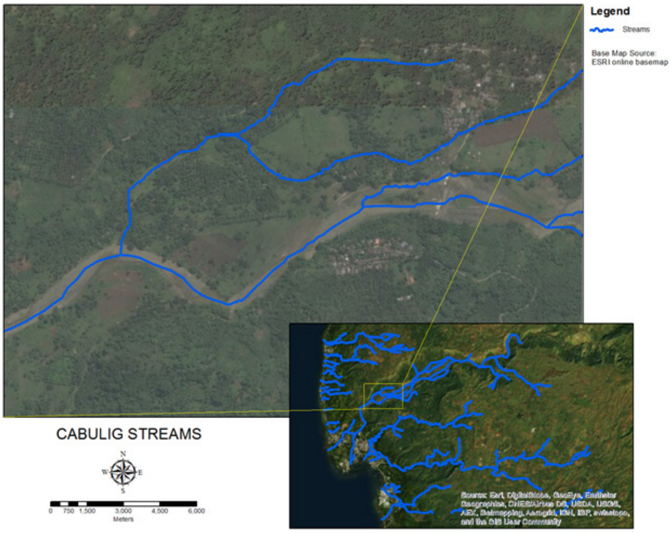

Figure 4. Stream Aerial Feature

Wetlands

Wetlands defined by Sharma et al., (2010) as those areas that are inundated or saturated by surface or ground water at a frequency and duration to support and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Hydrologically, wetlands are classed as surface-water depression, surface-water slope, ground-water depression, or ground-water slope wetlands. Precipitation comprises more than half of the inflow but the ground-water slope wetlands may provide as much as 90 percent of the inflow (Novitzki, 1982). The major method used in delineating inland wetlands was Stochastic Depression Analysis (SDA). The results were subjected to multiple filtering processes, field validation, and accuracy assessment. Out of 62 extracted polygons, 49 were corrected with the use of Google satellite and were subjected to ground validation. Ground validation used random sampling points which resulted to 75% extraction accuracy because some wetlands were found out as non-water only. Among the 49 corrected polygons there were 13 counts with area greater than 1000 m^2 that can be used as water impounding. In comparison, a study of Landmann et al., (2010) in mapping wetlands using well-corrected 250-meter MODIS time-series data for the year 2002 in West Africa has an overall accuracy of only 66.6%. Possible reasons for low accuracies are pixel variability, mapping errors, and vegetation dynamics within wetlands that make features challenging to assess even when high resolution data sets are used. Moreover, water impounding area will help farmer ensure crop intensification and diversification, improve farm income, minimize soil erosion and nutrient losses and prevent flooding of low-lying areas, and recharge groundwater (BSWM Primer, 2002). Figure 5 shows a sample of the aerial feature of wetland after field validation.

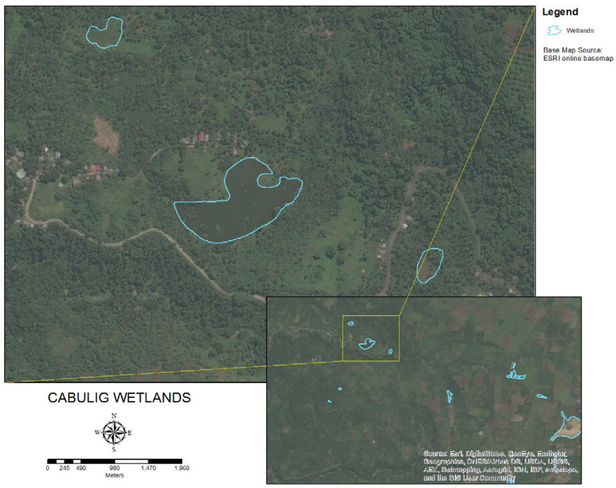

Figure 5. Aerial Feature of Validated Wetlands

Irrigation

Extracted irrigation feature shows the existence of the irrigation canals in the study area. The resulting lines after trimming would be used as a guide in digitizing the extracted data before importing into the geodatabase. This would minimize nodes and file size, making it easier to transfer and use the data. In this study, a total perimeter of 22,603.87 meters was extracted with a corresponding irrigable land served of 1,309,994 square meters. This source of information may help in monitoring water resources, irrigation network modelling, flood control planning. This would take into account even the smaller units like ditches, which are usually just made by farmers for irrigating their fields. Figure 6 shows a sample of the aerial feature of irrigation after field validation.

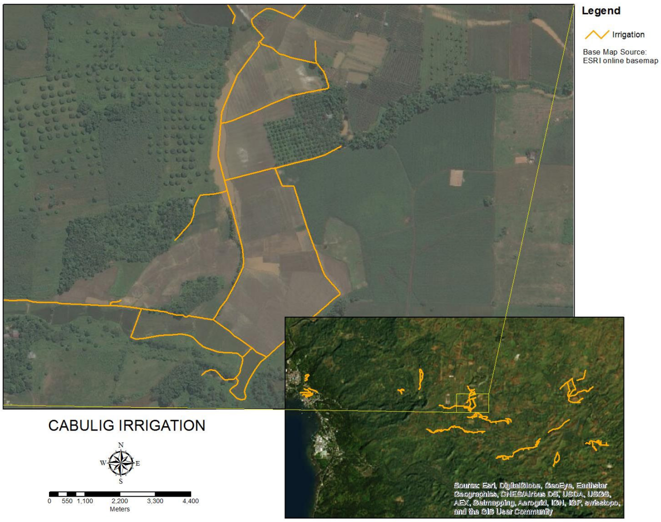

Figure 6. Aerial Feature of the Validated Irrigation

Field Validation

The uncertain features were subjected to field validation. The full error matrix and accuracy estimates or sometimes called the confusion matrix for accuracy assessment. Table 1 shows that the over-all accuracy or the average of all features during the field validation was 80%. Based on user accuracy the streams showed the highest accuracy of 90.48% while the wetlands extraction showed 70.59%. Figures 7-9 also shows the validated photos of different features.

Table 1
Confusion Matrix of the Validated Features

		REFERENCE					
		Wetlands	Streams	Irrigation	Non-Water	Column Total	User Accuracy
EXTRACTED	Wetlands	12	0	0	5	17	70.59
	Streams	0	19	1	1	21	90.48
	Irrigation	0	3	16	4	23	88.89
	Non-Water	0	0	0	10	10	100.00
	Row Total	12	22	17	20	71	80.28

Note: The confusion matrix is commonly used to calculate thematic accuracy based from the result of validation (validation through ancillary maps and through field)

Figure 7. Streams Point of Interest in Aerial View and Validated Stream in the Ground

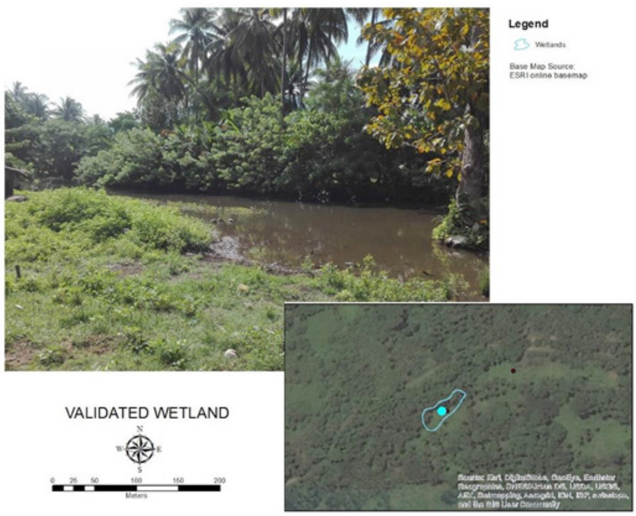

Figure 8. Wetlands Point of Interest in Aerial View and Validated Wetlands in the Ground

Figure 9. Irrigation Point of Interest in Aerial View and Validated Irrigation in the Ground

CONCLUSION

Hydrologic features of Cabulig watershed was successfully extracted using LiDAR-derived DTMs. The process in extracting the hydrologic features using LiDAR-derived DTMs showed higher levels of accuracy compared to lower resolution DEMs with 30 and 10 times more accurate compared to 30m. SRTM DEMs and 10m. SAR DEMs, respectively. The random sampling points for field validation resulted to an 85% average accuracy of extracted streams, wetlands and irrigation features. These extracted hydrologic features of Cabulig watershed could be used by policy makers and other stakeholders to ensure its proper management and conservation.

RECOMMENDATIONS

This study highly recommends to investigate whether the accuracy of the extracted hydrologic features will be improved significantly if dams and bridges that can interfere with the flow of the streams are removed from the LiDAR derived DEM. Using other source of DEM with higher resolution must be considered as well to increase its accuracy in finding more hydrologic features.

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