FLOOD RISK ASSESSMENT AS AFFECTED BY LAND USE CHANGE FOR POLICY INTERVENTION: CASE OF QUAIOIT RIVER WATERSHED IN NORTHERN PHILIPPINES

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KEY WORDS: Assessment, CLUMondo model, Flood risk, Land use/land cover change, GIS-AHP, SWAT model

ABSTRACT: Flood is one of the most destructive water-related disasters and flash flooding to hazard areas have already aggravated and tremendously uncontrollable due to human activities. Land use change, particularly on urbanization to meet human needs is very common. The adverse effects of these productivities have little exposure to land conversion actors that causes costly casualties that could cause even loss of life. To address this issue, existing technology were carefully evaluated and use in this study to come up with a foundation for this problem and for policy recommendations. Geospatial techniques were used such as the Soil and Water Assessment Tool (SWAT), Multi-Criteria Evaluation – Analytical Hierarchical Process (MCA-AHP) and Conversion of Land Use and its effects (CLUMondo model) to achieve a set goals of the study. Results revealed that problems on floods could always be quantified and mapped for proper compiling and can be used in hazard risk mapping. At the study area in Quiaot River watershed, conversion of agricultural land into commercial land cause a tremendous increase of flood extent up to 2.41 % of the total watershed exposed to very high susceptible to flooding. As well as converting forest land and grassland areas of about 50% of its total area would dramatically decrease safe areas of about 7.69%. For proper management, the study showed alternative solutions by constructing small water impounding systems and to increase river network water holding capacity to reduce overflow by adding some river networks. e land use plan of any towns or cities, incorporating the conjunctive use of surface and groundwater resources toward a sustainable supply of water resources to the community.

1. INTRODUCTION

Flood is known as one of the most destructive natural disasters due to its various kinds of casualties, from disease diffusion to loss of life. Flash flooding in urban and its tangential areas resulted from blocked or inadequate storm sewers and are flooded due to increased urbanization (Ajan et al, 2013) . Urban areas have high risk of flash flooding due to the presence of large impervious areas and sometimes inefficient drainage system (Chen et al, 2009; Danumah et al, 206).

Land use and land cover (LULC) disturbed both the probability of flood and its magnitudes in several ways. Land cover affects different elements of the water balance; evaporation, ground temperatures and interception (Stomesstrom et al, 2009) . In addition, LULC impacted climate systems, and, in turn, the frequency and characteristics of rainfall (Cornelissen et al, 2013; Boysen et al, 2014; Mitsova, 2014). Moreover, there is a direct impact of LULC on the formation of runoff from a particular rainfall event (Tellman, 2015). Finally, the land cover in river channels affects the conditions of hydraulic flow and contributes to, for example, woody debris jams on bridges (Bapalu and Sinha, 2005). LULC changes have implications for the consequence component of flood risk through increased development of settlements on flood-prone areas (Bhatt et al, 2014). Numerous studies have considered the general impact of land use change on flooding; however, there are fewer studies of the projected (simulated) impact of future land use on flood risk.

The Municipal of Paoay, Ilocos Norte, covering almost all the downstream area of the Quaioit River watershed faced great challenge on flooding. The municipality is almost a self-sufficient municipality because of its very attractive tourist spots (the UNESCO heritage Augustine Paoay Church and Paoay Lake). But because of flooding during peak season, casualties plus decrease of potential return from its attractive spots due to sever urban floods, inaccessible roads, crop productivity degradation and sedimentation. Unless, a very comprehensive land use plan of the municipality addressing the issue of flooding, this problem will be increasing annually.

Flood hazard mapping served a vital component for appropriate land use planning in flooded areas and mitigation measures (Bhatt et al, 2014). It provided accessible charts and maps which can be read easily and therefore facilitates the identification of hotspot risk areas by planners and this enable them to prioritize their mitigation efforts (Steffel et al, 2016; Kundzewicz et al, 2010). Flood management is necessary not only because flood imposes huge damages on the society, but for the optimal exploitation of the land and its proper management. This cannot become technically feasible without effective flood hazard and risk maps.

The study mainly focused on the assessment of flood risk mapping, simulating flood response to land use/land cover (LULC) conversion. Such assessment will lend support for further evaluation of possible solutions for policy intervention to address the issues.

2. MATERIALS AND METHODS

2.1. Locale of the Study

The Quiaoit River Watershed (QRW) has a total land area of 17,362.76 ha covering the City of Batac and Municipality of Paoay, Currimao, Banna and Sarrat, Ilocos Norte (Figure 1). About 61% of the total watershed area is located within Batac City and the second largest contributor of its area and almost covering its downstream is the municipality of Paoay which contributed 18% from the total area of the watershed, about 44.48% of the total area of the municipality. It is located in the northwest corner of the island of Luzon, about 11km from the eastern shores of the South China Sea. It summits as high as 520m above sea level. The watershed falls within latitude 17° 07’ North and longitude 120° 32’ to 120° 28’ East. The climate is Type I, with two pronounced seasons – dry (from Nov to Apr) and wet (June to Oct). The average annual rainfall is 2390 mm.

At present, the pattern of cultivation is closely related to the slope or landform. The level lowland areas are intensively cultivated and planted to rice during the wet season. During the dry season, corn, tobacco, and vegetables are planted. On the upland and hilly areas, agricultural activities are also common along the river, tapping its water for irrigation especially during the dry season. Most of the commercial activities are concentrated in the central and western parts of the watershed. The municipality of Paoay, Ilocos Norte, located in the downstream of the watershed, is frequently visited by typhoons because of its geographical locations. Devastations due to flooding are experienced since the municipality is the gateway of flood waters from the towns of Ilocos Norte towards the West Philippine Sea.

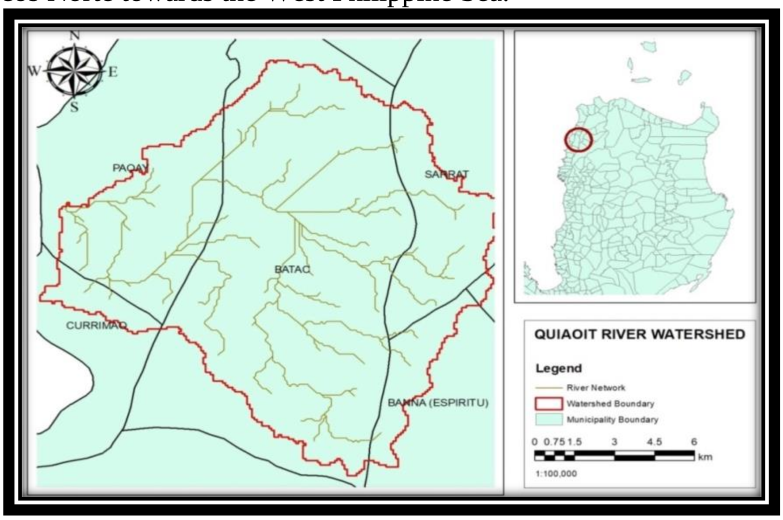


Figure 1. Location of QuiaoitRiver and watershed boundary, Ilocos Norte (Source: (Jimenez and Galeon, 2016).

2.2. Conceptual Framework

Three essential GIS-based tools were used in the study, namely: (1) SWAT; (2) –GIS-AHP; and (3) CLUMondo models (Figure 2). The application of SWAT to simulate the different relationship between land and water, especially runoff volumes and streamflow is important. Ancillary maps (DEM, soil and land use) were gathered from various implementing agencies. The resulting simulated runoff of the model was further calibrated using observed streamflow. Numerical values of soil and water relation maps and parameters were further extracted to come up with the list of criteria essential in GIS-AHP and suitability maps as independent input in the CLUMondo model. Criteria were reclassified into uniform format from 1 to 5, 5 as the most flooded areas and 1 as not affected by flood. Using these reclassified criteria, it was further simulated using the GIS-AHP to derive the flood extent of the watershed. CLUMondo was used ultimately to come up with a land use change, probably the expansion of inland water, to increase the water storing capacity of the watershed so it will possibly reduce the runoff during peak season.

2.3. Data Gathering

The Digital Elevation Model (DEM) with a pixel size of 90 by 90 meter resolution was gathered from the Quiaoit River Watershed Project of the Mariano Marcos State University, including the land use and soil map of Ilocos Norte. The Comprehensive Land Use Plan (CLUP) of the two municipalities that comprised the biggest contributor in terms of ancillary data was also gathered (Table 1). Meteorological data such as rainfall, humidity, solar radiation, wind and temperature were arranged and prepared according to the required format by SWAT model.

2.4. Preparation of Criteria Maps/Suitability Maps Needed in GIS-AHP and CLUMondo

From the results of SWAT simulation, some essential parameters were extracted and processed using GIS spatial toolkit to derived the different criteria, suitable maps needed in the simulation to GIS-AHP and CLUMondo, for flood hazard maps and alternative land use change for policy recommendation, respectively. The criteria used in the flood hazard mapping were: Flow Accumulation, Flow Direction, Land Slope, Elevation, Drainage Density and Runoff Volume (Figure 3). All of these thematic maps were gathered in the calibrated SWAT model. Processed maps were used for CLUMondo suitability maps and reclassified maps were used for GIS-AHP simulations. Dependent map used in CLUMondo simulation for policy interventions was the General Land Use (Figure 4).

2.5. Development of Land Use Scenarios

Projected land use patterns expected to happen in the future, due to increasing demand of human needs, based on the CLUP of two involved municipalities were derived to predict the response of flood water behavior when there are conversion of land use without proper allocation. Table 2 shows the scenarios of land use conversion to showcase the effect of land use change to runoff depth. Scenario 1 involved the projected land use conversion of the two municipalities in the watershed, Paoay and City of Batac. About 25% percent was projected to convert from Agricultural Land to Commercial Land in the Urban Areas due to urban commercialization that are mandated in the CLUP of both municipalities. Scenario 2 involved the projected land use conversion of the urban areas plus the demand of abrupt increase of population by converting shrub land into productive agricultural land by about 50% and, the forest areas into grass land and shrub areas by about 50 % due to deforestation.

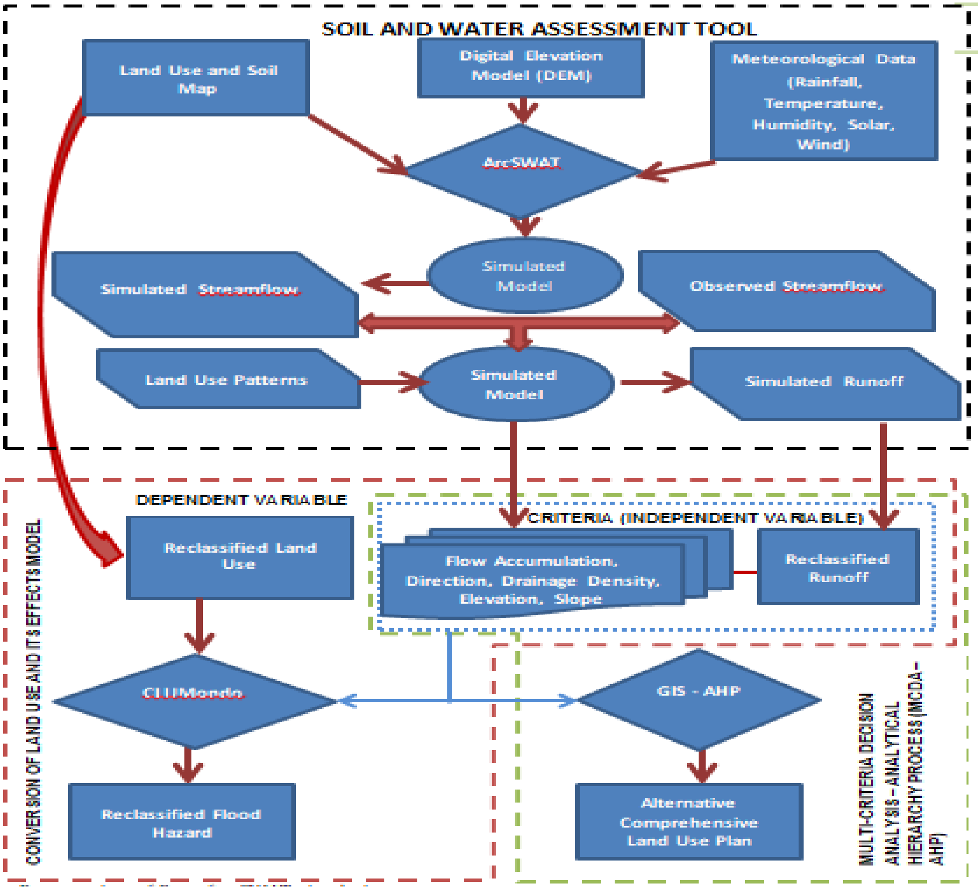


Figure 2. Research framework of the flood risk mapping assessment using GIS-based tools and land use model.

3. RESULTS AND DISCUSSION

3.1. Calibration of Streamflow Using SWAT Model

The simulated streamflow using SWAT model was further calibrated to validate the effectiveness of the model. The correlation r value and the Nash and Sutcliff Coefficient (NSE) were used to test the adequacy of the model. Calibrated streamflow of the stations gathered from the Crop Research Laboratory of Mariano Marcos State University were requested as basis of the calibration [11]. Table 3 shows the variation of correlation, r and NSE with respect to stations. Correlation **r** values ranged from 0.63 to 0.92 which proves that as the simulated streamflows increases, observed streamflows also increases, and vice versa. NSE values ranged from 0.34 to 0.87 which indicated that the model was better predictor than the mean. This meant that SWAT model simulated was efficient and effective to simulate the relationship of the water behavior to land conversion. Figure 5 shows the variation of response of peak flows (calibrated and simulated) during heavy rains.

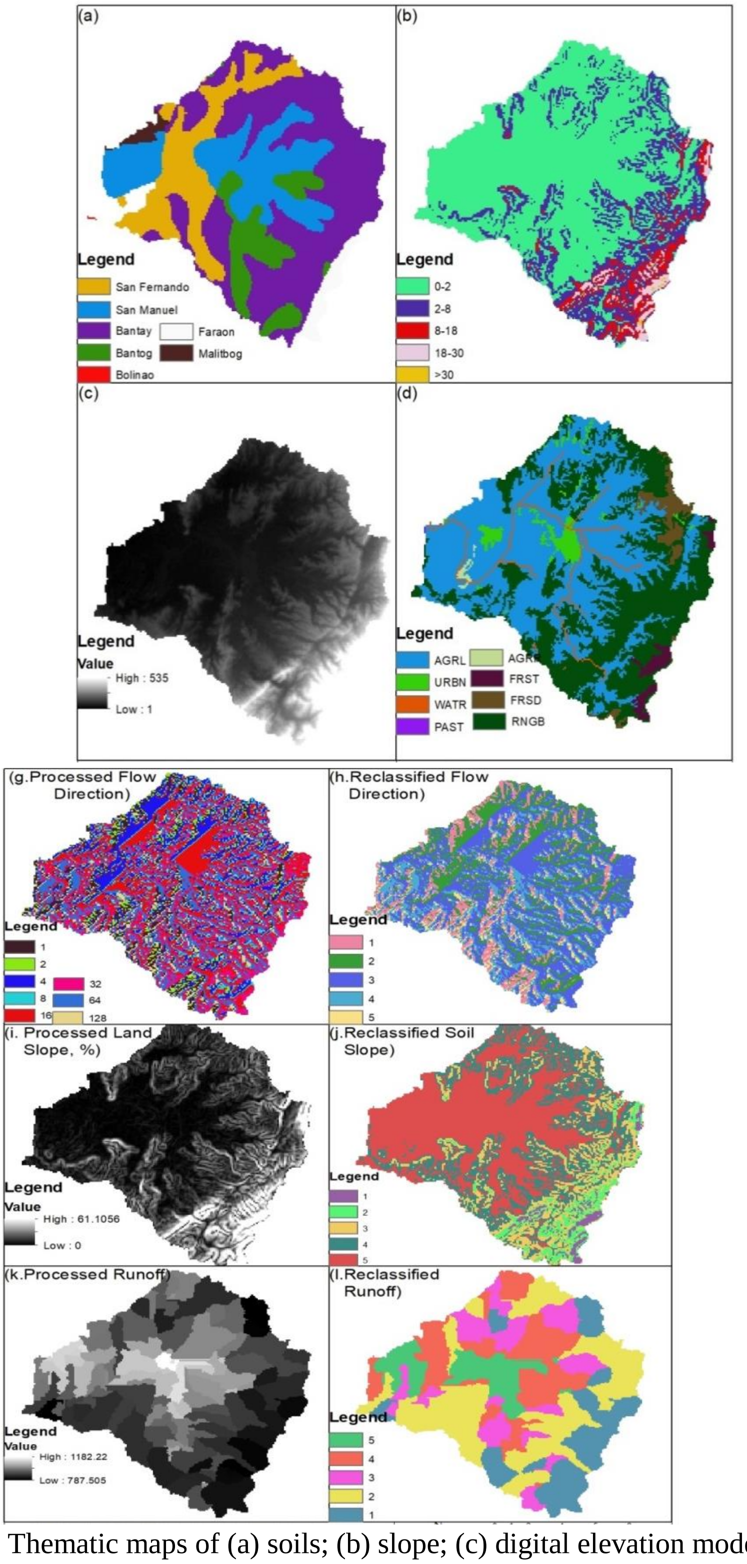


Figure 3. Thematic maps of (a) soils; (b) slope; (c) digital elevation model; and (d) land use and reclassified simulated results of SWAT of Quaioit River watershed for GIS-AHP and CLUMondo Maps/Criteria.

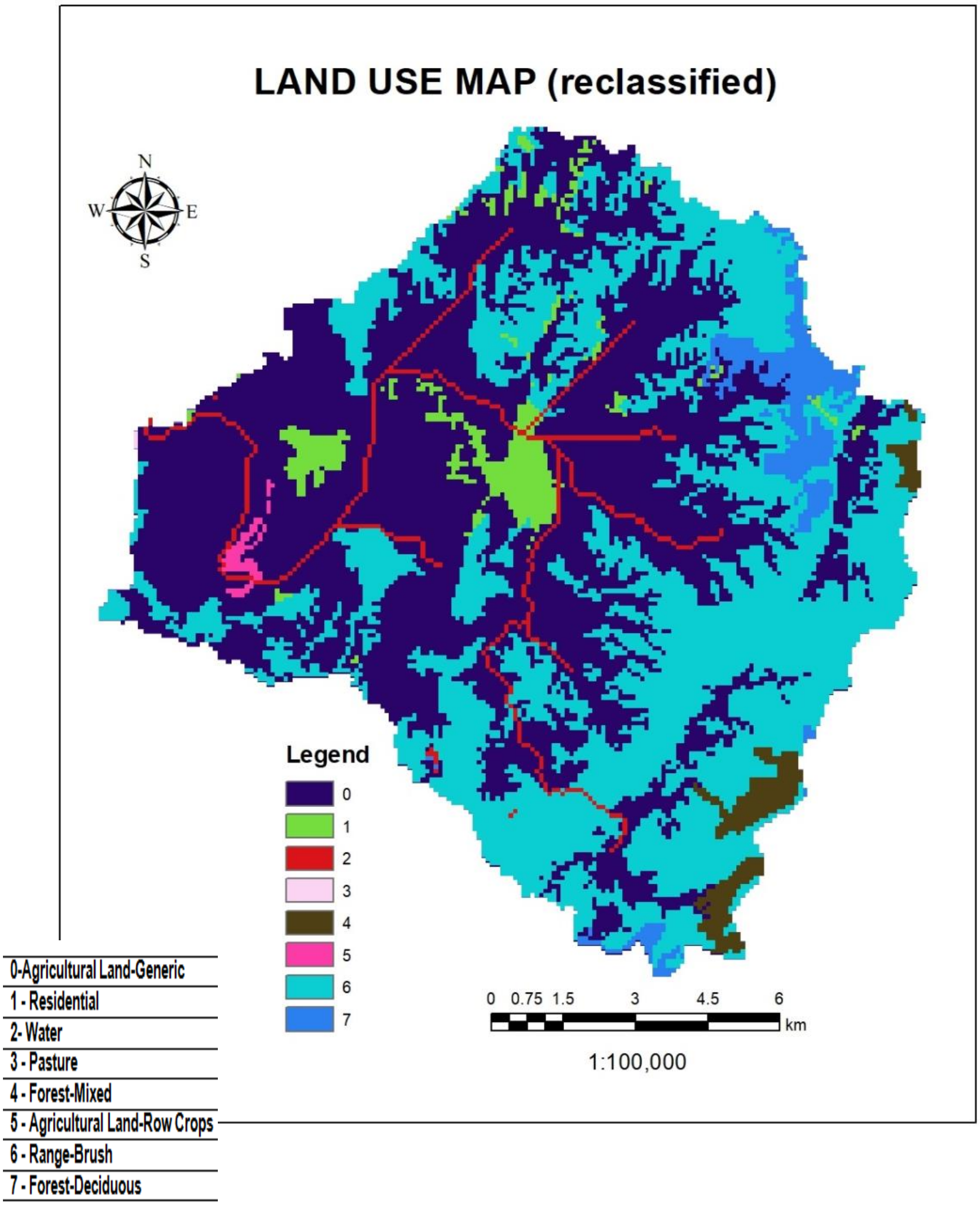


Figure 4. Land use thematic map result of the Quaiot River watershed using CLUMondo model.

Table 1. Land use, soil types and slope distribution in the study area.

THEMATIC MAP	DESCRIPTION /NAME	SYMBOL	AREA (ha)	PERCENT of TOTAL AREA (%)
LANDUSE				
	Agricultural Land-Generic	AGRL	8949.35	51.54
	Residential	URBN	571.11	3.29
	Water	WATR	8.37	0.05
	Pasture	PAST	3.34	0.02
	Forest-Mixed	FRST	338.31	1.95
	Agricultural Land-Row Crops	AGRR	66.99	0.39
	Range-Brush	RNGB	6848.29	39.44
	Forest-Deciduous	FRSD	576.97	3.32
		Total	17362.75	100
SOILS				
	Bantay	Bantay	7749.35	44.63
	Bantog	Bantog	1786.18	10.29
	Beach	Beach	453.87	2.61
	Bolinao	Bolinao	5.02	0.03
	Faraon	Faraon	503.28	2.9
	Malitbog	Malitbog	201.81	1.16
	San Fernando	San Fernando	2996.23	17.26
	San Manuel	San Manuel	3666.99	21.12
SLOPE:		(%)		
	Flat	0-2	5148.36	29.65
	Relatively flat	02-08	6764.56	38.96
	Undulating	08-18	3959.25	22.8
	Steep	18-30	1089.46	6.27
	Very Steep	> 30	401.11	2.31

Table 2 Land use scenarios used in the flood assessment.

SCENARIO	LAND USE	CONVERT TO	PERCENT OF AREA (%)
Scenario 1	Agricultural Land	Commercial Land	25
Scenario 2	Agricultural Land	Commercial Land	25
	Shrub to Grass Land	Agricultural Land	50
	Forest Land	Shrub to Grass Land	50

Table 3. Statistical indicator during calibration using SWAT model.

STATISTICAL PARAMETER	CORRELATION, r	NSE
STAT 1	0.63	0.34
STAT 2	0.76	0.41
STAT 3	0.92	0.87
STAT 4	0.75	0.64
STAT 5	0.91	0.71

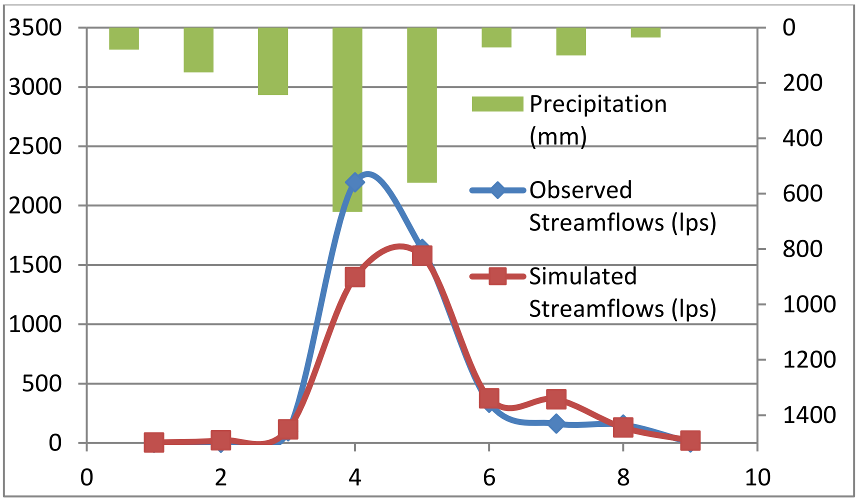


Figure 5. Response of streamflow runoff to peak rainfall using SWAT model.

3.2. Flood Hazard Mapping Using GIS-AHP

Essential processed six (6) thematic map as set of criteria by the resulting calibrated SWAT model were further extracted from the model to simulate flood hazard map. Using the MCA-AHP with resulting percent weights at consistency ratio of less than 1%;the flow direction (10.1%), flow accumulation (10%), slope (22.6%), elevation (31.5%), drainage density (21.7%), and annual runoff (4.1%) were all gathered and prepared to required format from the calibrated SWAT model. For such GIS-AHP model, elevation had the highest weight to look for the low lying areas. Next is the land slope to find the areas wherein there are great flows. Drain density was also considered to showcase the effect of low draining density to flood behavior. Other criteria used were flow accumulation, flow direction and of course, annual runoff as a product of land use pattern, precipitation and land cover. Figure 6 shows the resulting flood hazard of the QRW and the two flood hazards is the Municipality of Paoay extracted from the map. The upper left figure is the modelled flood map and the right one is the existing flood map of Paoay Ilocos Norte. Both of these maps have little similarities but show a significant areas of Paoay exposed to floodings.

3.3. Flood Response at Different Land Use Pattern

This section demonstrated the effect of land change with response to aggregate conversion of land use change into more susceptible to flooding, e.g. agricultural land to commercial. As stated before, that in order for a society to improve its economic status is to maximize its resources minimizing the casualties. But with the traditional conversion of land into productive one which is maximizing the land resources but maximizing casualties. In this section, one disaster was used to demonstrate the effect of land use change, e.g., floods. Figure 7 show the extent of flooded areas at different scenarios. To come with the objective of this section, Typhoon *Pepeng* in 2009 was considered in the simulation to showcase the most possible occurrence of floods during peak season. It drops of 843.40 meters in the watershed. At Scenario 1 (conversion of agricultural land into commercialize land), an increase of 2.41% from the total areas was added as very susceptible areas while reduction of 2.16% was not merely affected. In Scenario 2 (additional conversion of grassland into agricultural land and forest land into grassland), a very high reduction of not affected of about 7.69% of not affected or very low affected. Most of the susceptible areas to flooding risks were located in the urban areas and agricultural land areas that these areas will give very high cost of casualties due to flooding.

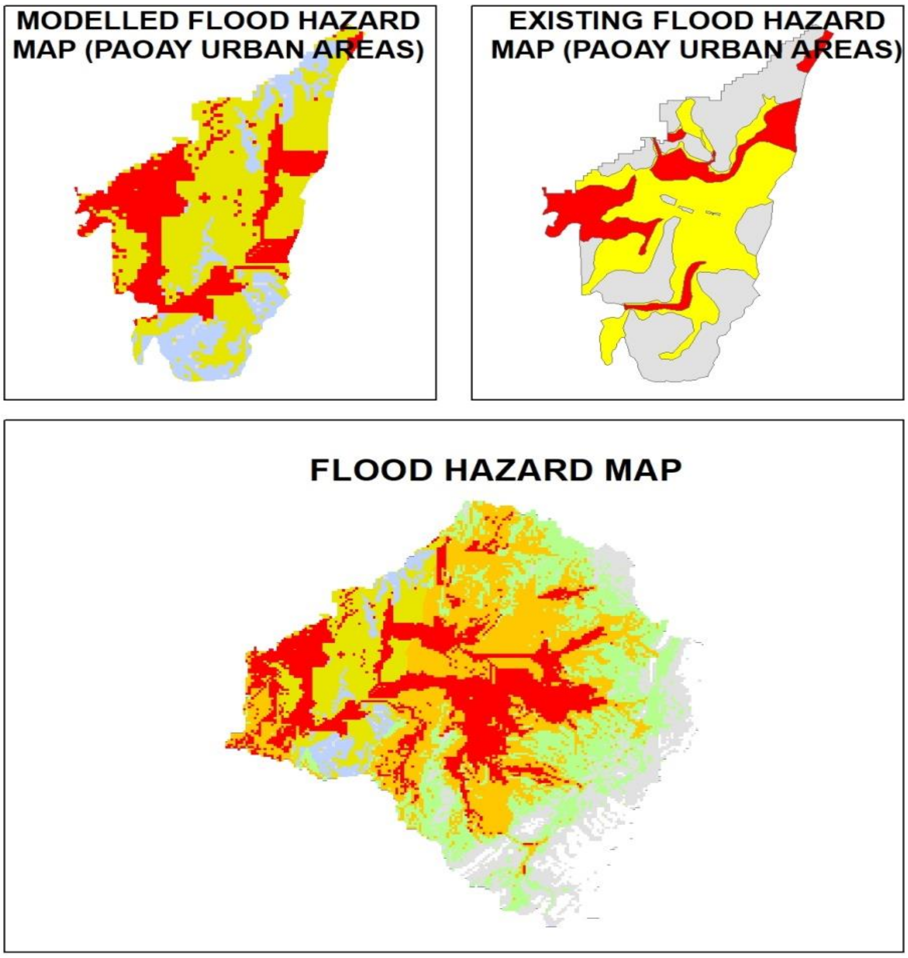


Figure 6. Flood risk assessment of the Quiaoit River watershed and urban areas of Paoay, Ilocos Norte, Philippines.

4.4 Policy Intervention for Land Use Change

In every conversion of agricultural land into commercial land will adversely affect the extent of flood water increasing the affected and could increase casualties in the watershed. In this section, some solutions were presented to address the issue of flood water in response to conversion of water. A first solution is by providing alternative stream networks to increase stream discharge capacity of the watershed considering those that has very low drainage density. This intervention is to decrease overflow in stream bed in the watershed that contributed in flood water.

Figure 8 shows the best location in the watershed to construct additional stream networks. One network was located in the vicinity of Paoay and the other one is located upon the area of the City of Batac. These locations are the area that is mostly affected by flood water during peak seasons.

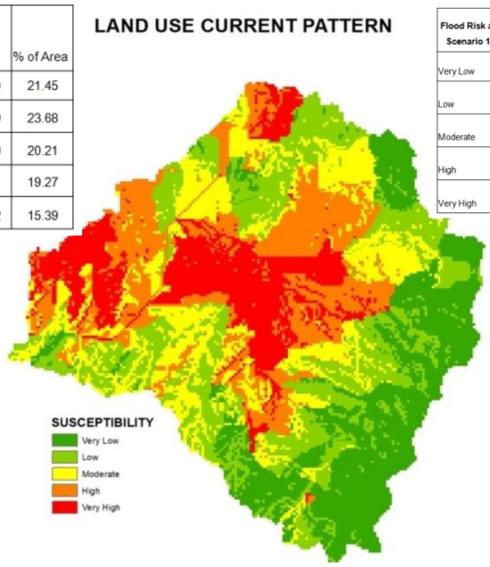
Another solution is by locating areas that are potential sites for constructing small water impounding projects (SWIPs). SWIPs are artificial reservoirs that can impound water during peak seasons that can be used during water-scarce months, mostly in summer time. Figure 9 shows the possible locations in the watershed that have high possibility of constructing SWIPs for future use. There are suitable areas simulated using the CLUMondo. Most of these SWIPs are located on the upstream of the watershed located in the upper area in the City of Batac. But one vast site that could have great volume of water can impound is located in the municipality of Paoay. The land use that can be converted in to water bodies is from pasture land which is not utilized and could maximize its purpose of constructing SWIPs.

4. CONCLUSION

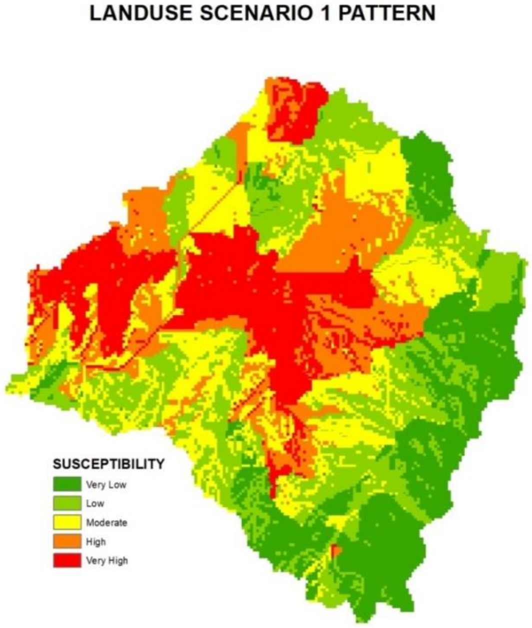
The combined-use of GIS-based tools such as SWAT, GIS-AHP and CLUMundo are indispensable tools in integrating, organizing, processing and visualizing the comprehensive land use plan for policy interventions. Its application is fundamental to the efficient and effective creation of thematic maps in a GIS environment has been a very effective way of conveying the flood risk assessment as impacted by land use changes at different scenarios for policy intervention on updating their CLUPs.

With more and high resolution, multi-spectral, and temporal of spatial data are captured and improved land use models results and decision maps become available. Also, developing and improving geo-referenced data and information management of land and water resources in the comprehensive land use plan of towns and cities to effectively handle all the information will remain a challenge to future land use planners. Thus, enhancing courses to incorporate more topics in GIS and remote sensing tools in schools and various training-workshops are recommended.

Flood Risk at Current Land Use	Area (ha)	% of Area
Very Low	3723.20	21.45
Low	4108.89	23.68
Moderate	3506.49	20.21
High	3344.31	19.27
Very High	2670.72	15.39



Flood Risk at Scenario 1	Area (ha)	% of Area
Very Low	3347.95	19.29
Low	4220.63	24.32
Moderate	3759.13	21.66
High	2936.71	16.92
Very High	3089.21	17.80



Flood Risk at Scenario 2	Area (ha)	% of Area
Very Low	2389.04	13.77
Low	4759.23	27.42
Moderate	4119.96	23.74
High	3147.33	18.14
Very High	2938.06	16.93

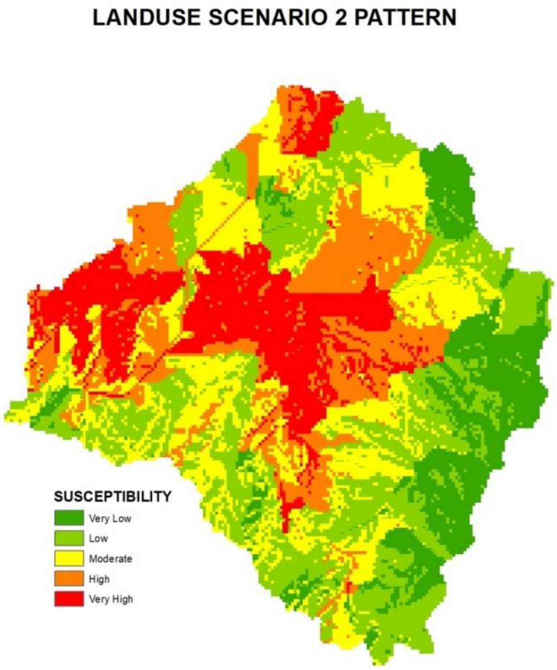


Figure 7. Flood risks at different land use pattern scenario at the Quaioit River Watershed, Philippines.

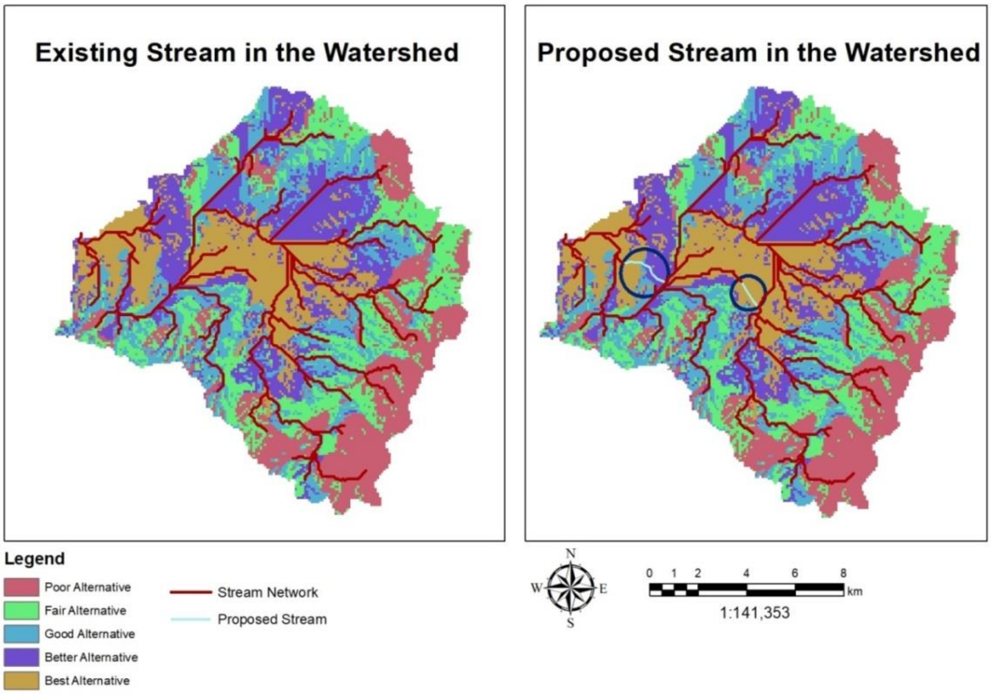


Figure 8. Existing and proposed alternative stream networks at the Quiaoit River Watershed, Philippines.

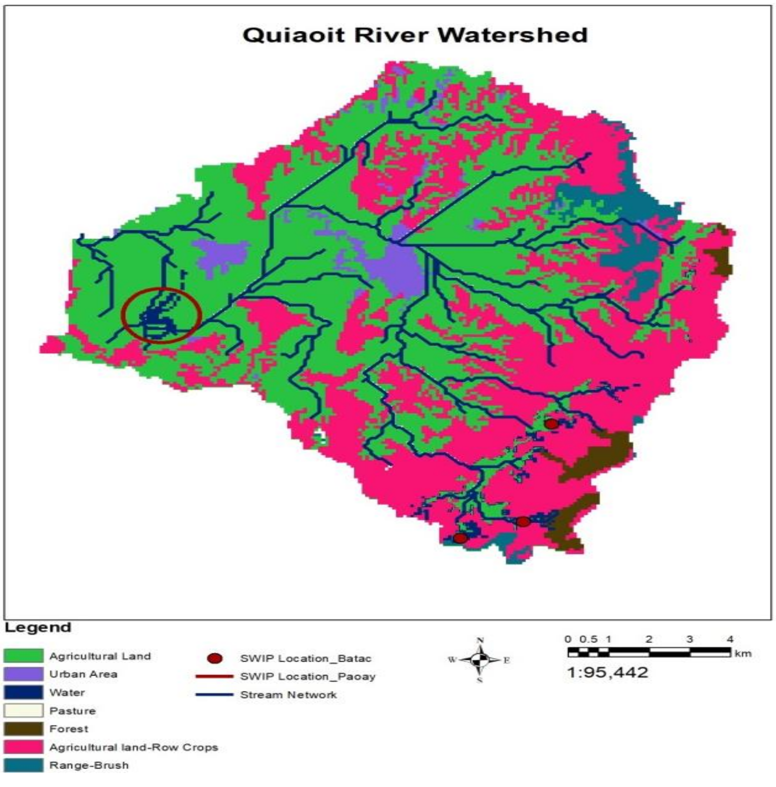


Figure 9. Proposed location of small water impounding projects at the Quaioit River Watershed, Philippines.

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