Comparison of Two Land Cover Scenarios and its Effect on theRunoff and Flooding inside the Mandulog River Basin, Philippines

Milano, Alan E., Suson, Peter D., Salcedo, Stephanie Mae B. andBlasco,Jennifer G.

Abstract:

This study aims to determine the effect on runoff and flooding when no proper land use management is done and another is when sound land use management is adopted. Hence, two (2) land cover/use scenarios were created. The first is the Projected Land Cover, where land cover was projected 10 years after the latest available landcover dataset. The second is the Proposed Land Use wherein it makes use of slope, elevation and distance from the river as the basis in assigning the different land uses. Hydrologic and hydraulic modelling was done at different rainfall conditions. The Projected Land Cover has a higher total runoff volume, peak flow and shorter Lag time as compared to the Proposed Land Use in four (4) Rainfall scenarios.The results also shows that the effect on flooding by Projected Land Cover shows more areas have been flooded with more areas inundated with higher flood depth level as compared to the Proposed Land Use in the same rainfall scenarios.The study shows when land cover conditions are left by itself without any intervention to stop land conversion, flooding is more likely to be magnified. The study also shows that flood can be mitigated if the Proposed Land Use scenario will be adopted.

Keywords:*flooding, runoff, land cover, land use*

I. INTRODUCTION

The Mandulog River Basin is located in Northern Mindanao, Philippines with coordinates at 8°00’N to 8°20’N Latitude and 124°15’ E to 124°35’E Longitude. The downstream of the basin is Iligan City; a highly urbanized city. In December 17, 2011 Tropical Storm Washi struck the city. An updated assessment shows that 1,278 died, 28,730 families displaced, 35 out of the 44 villages were affected and initial structural damage assessment was about USD 81.4 Million[1]. It is because of that fateful event that there has been an interest in studying the flooding behavior of the watersheds traversing Iligan City .

This study aims to determine what happens to runoff and flooding after some given time in the absence of any intervening land use management wherein deforestation is on-going and compare it when sound land use management is adopted. In that light, two (2) scenarios were created. One is the Land Cover projected 10 years fromthe available 2010 land cover dataset which is termed here as the 2020 Projected Land Cover and the other scenario is the Proposed Land Use, where it matches land uses with the slope.The ultimate goal of this simulation study is to provide information and persuade the local planning and decision making bodies to seriously adopt and implement sound land use management plan and practices. Currently there is no deliberate measure to design land use planning inside the basin to mitigate flood.

II. METHODOLOGY

The Projected Land Cover scenario in 2020 was created using a Trend Analysis function from MS Excel derived from available geospatial vector data of 1998, 2004 and 2010 land cover scenarios to get the area in hectares of the different land cover classes and edited the 2010 land cover shape file in a GIS software in accordance to the area of the different land cover classes at year 2020. On the other hand, the Proposed Land Use makes use of slope as the basis in assigning the different land uses. Specifically, agriculture and built-up were assigned to 0-18% slope, 18-30% slope for agroforestry, 30-50% for production forest and >50% for protection forest. A slope vector file was created from a slope raster file. The slope raster file in turn was derived from an integrated Digital Elevation Model (DEM). The DEM is mostly of the Interferometric Synthetic Aperture Radar (IFSAR) has a resolution of 5m but it was integrated with the limitedly available Light Detection and Ranging Digital Elevation Model (LiDAR DEM) which has a resolution of 1m to produce a more detailed slope geospatial data. Furthermore, a river buffer zone was assigned and which consist of three (3) buffer zones. These were the Protection Forest Riparian zone (0-20 m from the river), the Production Forest Riparian zone (20-60 m from the river) and the Urban River Buffer Zone (0-2 m from the river). Also a Protected Area was assigned to areas with more than 1,000 masl. Finally for the Built-up area, it was based on the current extent using the Google Earth Image.The difference between the Projected Land Cover and the Proposed Land use is that the projected land cover shows what happens to the land cover after 10 years based on the latest available land cover data which is 2010. The underlying assumption of which is that land cover conditions are left by itself without any intervention to stop land conversion. On the other hand, the Proposed Land Use makes use of land conservation principles and environmental policies that will promote soil and water conservation via the enhancement of forest vegetation cover on critical slopes.

Determining the Runoff behavior revolves around the concept and equation postulated by the Soil Conservation Service (SCS) method. The SCS method can be selected as a function or a modeling method in the HEC-HMS (Hydrologic Engineering Center-Hydrologic Modeling System) software. To make the two (2) scenarios SCS ready, these were intersected with another available geospatial vector file called Soil Hydrological Group. After which these two (2) scenarios together with the integrated DEM were fed into the HEC-GeoHMS (Hydrologic Engineering Center-Geospatial Hydrologic Modeling System) software for basin model and initial preparation of the parameters. Once the preparations have been made, the HEC-HMS was used for simulating the runoff of the Projected Land Cover and the Proposed Land Use. These two (2) scenarios were compared in terms of Runoff volume, Peak Flow and Lag Time for four (4) Rainfall Return Period (RRP) scenarios. Theseare 5 years, 25 years, 50 years and 100 years. Details on the use of the HEC-GeoHMS and HEC-HMS are well described by a previous study[2].

The output on the impact of the Projected Land Cover and the Proposed Land Use to runoff in the previous study was used as an input to determine the impact of the aforementioned land cover scenarios to flooding. The software that was used to determine flooding was the Hydrologic Engineering Center's- River Analysis System (HEC-RAS) 2D model and a GIS extension application called HEC-Geo-RAS. The LiDAR-DTM (Light Detection and Ranging-Digital Terrain Model) bathymetrically burned geospatial raster dataset was the input used for the software processing of the flood. The flood parameters that were determined was flood depth/level and extent for the different rainfall return periods (RRP) in particular the 5 year, 10 year, 25 year, 50 year and 100 year. There were three flood depth or level that were determined, this was low, medium and high with corresponding values in range namely: 0-0.5 m, 0.5-1.5 m and >1.5 m.Geometric data was prepared in HEC-RAS by manually delineating the 2D area and generating a 50x50 mesh.

Unsteady flow was simulated for 5,10,25,50 and 100yr RRP in 10min flow data interval with an EG Slope of 1 and a minimum flow of 27 m3/s. Animation and visualisation was done in RAS Mapper which is also capable in exporting flood map results in files readable to GIS.

III. RESULTS AND DISCUSSION

A. RUNOFF

1. Projected Land Cover

Table 1.1 shows the land cover classification and area of the 2020 Projected Land Cover which was derived using the trend analysis function of MS Excel based on the temporal land cover of 1973, 1989, 1998, 2008 and 2010. Based on that table, there has been an increase in the area for agriculture, built-up, open forest, open space and shrubs while there has been a decrease in the area for coconut and grassland. Closed Canopy Forest will disappear. Table 1.2 shows the land cover proportion of the 2020 Projected Land Cover wherein forest cover constitutes only 25.03% of the whole river basin area. More over the quality of the forest is not that good in so far as reducing surface runoff is concern since the dominant type of forest cover is classified as Open Canopy Forest. This means that the presence of tree vegetation does not completely protect the soil from rainfall impact.

Table 1.1. Land cover classification and area of the 2020 Projected Land Cover

Landcover (hectares)	1998	2004	2010	2020
1. Brushland	10,324.05	19,343.13	14,793.24	0.00
2. Built-Up	722.91	291.67	496.80	1,754.32
3. Closed Canopy Forest	39,974.93	31,810.12	23,691.29	7,796.97
4. Cultivated Area	5,012.63	4,411.56	5,377.04	8,186.81
5. Grassland	5,578.60	2,381.06	7,234.48	25,817.55
6. Open Canopy Forest	11,660.44	17,786.07	20,044.71	11,695.45
7. Perennials	4,588.73	1,838.69	6,224.72	22,611.20
TOTAL	77,862.30	77,862.30	77,862.30	77,862.30

Table 1.2. Land cover proportion of the 2020 Projected Land Cover

2020 Projected Land Cover	Hectares	%
1. Brushland	0.00	0.00
1. Built-up	1,754.32	2.25
2. Closed Canopy Forest	7,796.97	10.01
3. Cultivated Area	8,186.81	10.51
4. Grassland	25,817.55	33.16
5. Open Canopy Forest	11,695.45	15.02
6. Perennials	22,611.20	29.04
Total	77,862.30	100.00

2. Proposed Land Use

Table 2 shows the land use area and proportion of the Proposed Land Use. As can be gleaned from the table the total forest cover is 70.13% this is thrice as much as that of the projected land cover scenario. Moreover the percentage of forest that maintained solely for protection (Protection Forest, Protected Area and Protection Riparian Forest) is 40.82 %. Forest vegetation is known to improve soil infiltration by improving and/or maintaining soil macropores. Macroporosity is a good predictor of infiltration capacity[3]. In addition, the agroforestry land use which is about 15.24% of the total river basin area is known to sufficiently prevent rain induced erosion and conserve water via improved infiltration[4].

Table 2. Land use area and proportion of the Proposed Land Use

Proposed Landuse	Land Features	Area (hectares)	%
1. Agriculture	0-18% slope	10,881.81	13.98
2. Agroforestry	18-30% slope	11,869.55	15.24
3. Production Forest	30-50% slope	17,575.90	22.57
4. Protection Forest	>50% slope	18,067.90	23.20
5. Protected Area	>1000 masl	11,096.86	14.25
6. Built-up	Derived from the current Google image	493.84	0.63
7. Protection Riparian Forest	0-20 m from the river	2,622.13	3.37
8. Production Riparian Forest	20-60 m from the river	5,244.27	6.74
9. Urban River Buffer Zone	2 m from the river	10.04	0.01
TOTAL		77,862.30	100.00

3. Projected Land Cover scenario versus Proposed Land Use scenario

To meaningfully compare theProjected Land Cover with the Proposed Land Use in relation to mitigating flood it is important to compare these two land cover scenarios in terms of their total forest vegetation. Table 3.1 shows that the Proposed Land Use has a lot more forest cover (70.13%) than the 2020 Projected Land Cover which is 25.03%.

Table 3.1. Total Forest Cover of the 2020 Projected Land Cover and the Proposed Land Use

2020 Projected Land Cover	%	Proposed Landuse	%
1. Closed Canopy Forest	10.01	1. Production Forest	22.57
2. Open Canopy Forest	15.02	2. Protection Forest	23.20
		3. Protected Area	14.25
		4. Protection Riparian Forest	3.37
		5. Production Riparian Forest	6.74
TOTAL	25.03		70.13

Tables 3.2 to 3.6 graphically illustrates that the Proposed Land Use scenario has lower peak outflow of runoff and total runoff volume and longer lag time between peak rainfall and peak runoff outflow than the 2020 Projected Land Cover in the 5 year, 10 year, 25 year, 50 year and 100 year Rainfall Return Period. The numerical values for the differences are shown in Tables 3.1 to 3.5. The reason for the results is that the Proposed Land Use scenario has more than twice the amount of forest vegetation as compared to the 2020 Projected Land Cover, it has better forest cover quality in the presence of the protection forest wherein degree of cover is similar to that of a Close Canopy Forest. In addition, the Proposed Land Use scenario has a 19% agroforestry land use which is known to promote soil and water conservation.

Table 3.2. Five (5) Year Rainfall Return Period (RRP); Proposed Land Use vs. 2020 Projected Land Cover

Parameters	Proposed Land Use	2020 Projected Land Cover	Difference
Total Rainfall (mm/day)	141.89	141.89	
Peak Rainfall (mm)	24.50	24.50	
Peak outflow (m3/s)	907.10	2,049.50	-1160.5
Total Runoff Volume (m3)	57,634.50	110,146.70	-63644.5
Time to Peak	17 hours and 50 minutes	17 hours	50 minutes
Lag Time	5 hours and 50 minutes	5 hours	50 minutes

Table 3.3. Ten (10) Year RRP; Proposed Land Use vs. 2020 Projected Land Cover

Parameters	Proposed Land Use	2020 Projected Land Cover	Difference
Total Rainfall (mm/day)	300.49	300.49	
Peak Rainfall (mm)	37.00	37.00	
Peak outflow (m3/s)	2,753.20	5,118.10	-1160.5
Total Runoff Volume (m3)	157,245.80	269,210.00	-63644.5
Time to Peak	18 hours	16 hours and 40 minutes	1 hour and20 minutes
Lag Time	6 hours	4 hours and 40 minutes	1 hour and20 minutes

Table 3.4. Twenty- Five (25) Year RRP; Proposed Land Use vs. 2020 Projected Land Cover

Parameters	Proposed Land Use	2020 Projected Land Cover	Difference
Total Rainfall (mm/day)	373.89	373.89	
Peak Rainfall (mm)	44.00	44.00	
Peak outflow (m3/s)	907.10	6,588.80	-1160.5
Total Runoff Volume (m3)	210,865.20	348,119.50	-63644.5
Time to Peak	17 hours and 50 minutes	16 hours and 30 minutes	1 hour and20 minutes
Lag Time	5 hours and 50 minutes	4 hours and 30 minutes	1 hour and20 minutes

Table 3.5. Fifty (50) Year RRP; Proposed Land Use vs. 2020 Projected Land Cover

Parameters	Proposed Land Use	2020 Projected Land Cover	Difference
Total Rainfall (mm/day)	427.59	427.59	
Peak Rainfall (mm)	49.20	49.20	
Peak outflow (m3/s)	4,462.90	7,680.30	-1160.5
Total Runoff Volume (m3)	252,122.40	406,818.20	-63644.5
Time to Peak	17 hours and 50 minutes	16 hours and 30 minutes	1 hour and20 minutes
Lag Time	5 hours and 50 minutes	4 hours and 30 minutes	1 hour and20 minutes

Table 3.6. One Hundred (100) Year RRP; Proposed Land Use vs. 2020 Projected Land Cover

Parameters	Proposed Land Use	2020 Projected Land Cover	Difference
Total Rainfall (mm/day)	481.16	481.16	
Peak Rainfall (mm)	54.40	54.40	
Peak outflow (m3/s)	5,206.80	8,760.70	-1160.5
Total Runoff Volume (m3)	293,939.60	465,682.70	-63644.5
Time to Peak	17 hours and 40 mins	16 hours and 20 mins	1 hour and20 minutes
Lag Time	5 hours and 40 mins	4 hours and 20 mins	1 hour and20 minutes

B. FLOOD

Flood depth or level is lower in the Proposed Land Use than the 2020 Projected Land Cover and this is much pronounced at higher flood level or depth in all of the rainfall return period events (Figures 2.1 to 4.5). Likewise the total extent of flooding is much lower in the Proposed Land Use than the 2020 Projected Land Cover as also shown in Figures 2.1 to 4.5.

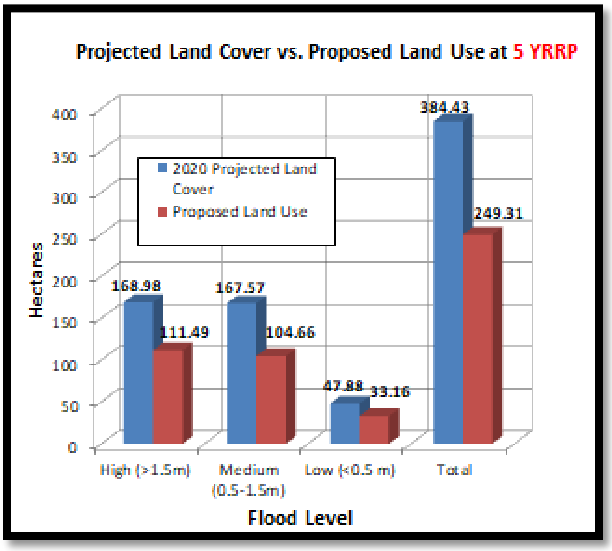

Figure 2.1. Extent of Flood Level at 5 Year Rainfall Return Period

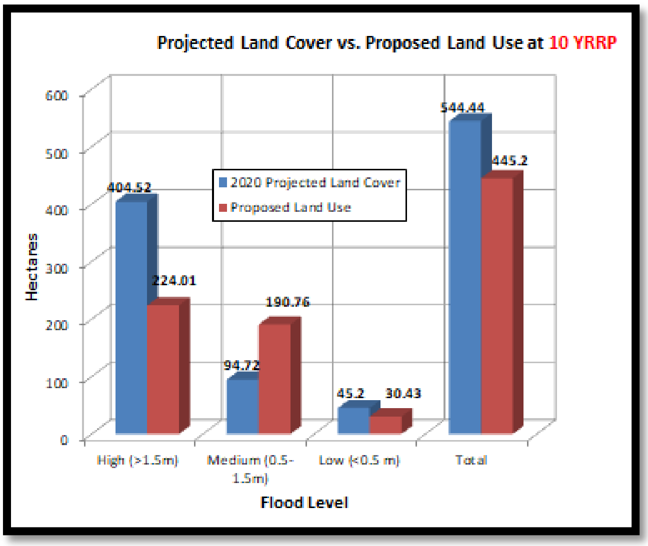

Figure 2.2. Extent of Flood Level at 10 Year Rainfall Return Period

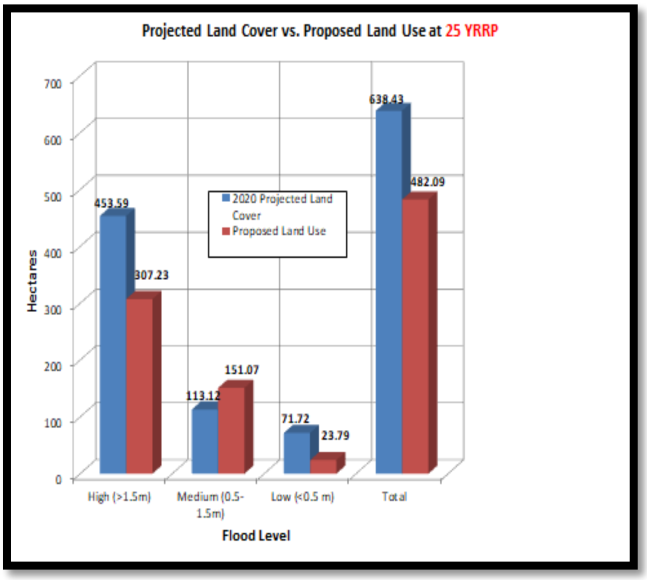

Figure 2.3. Extent of Flood Level at 25 Year Rainfall Return Period

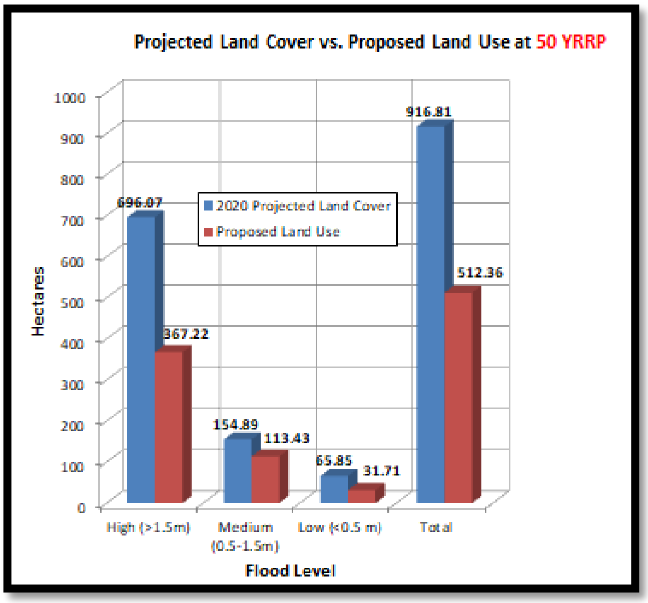

Figure 2.4.Extent of Flood Level at 50 Year Rainfall Return Period

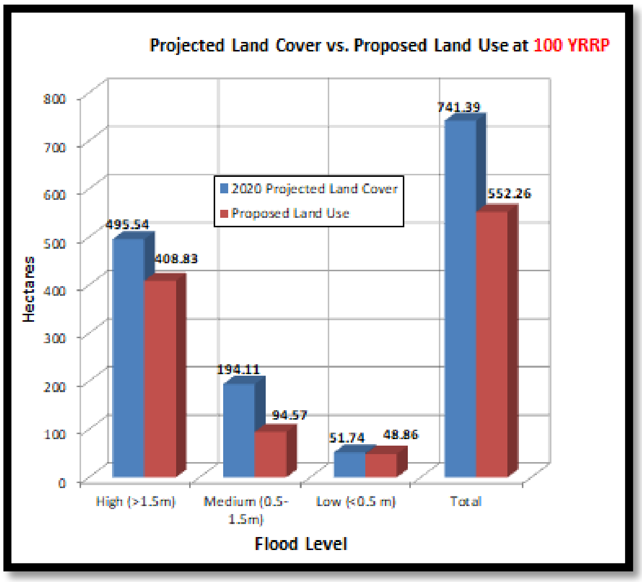

Figure 2.5.Extent of Flood Level at 100 Year Rainfall Return Period

The reason for a lower flood depth and extent for the Proposed Land Use than the 2020 Projected Land Cover is because as what has been aforementioned in the Runoff discussion section, the Projected Land Cover has higher runoff values in terms of discharge volume, peak discharge and Lag Time as against the Proposed Land Use scenario. This is in view of the fact that runoff is the major source for flood waters.

IV. CONCLUSION

The study shows when land cover conditions are left by itself without any intervention as represented by the 2020 Projected Land Cover scenario, the impact of flood disaster is more likely to be magnified due to higher peak runoff flow and total runoff volume and shorter lag time The study also shows that flood disaster can be mitigated if the Proposed Land Use scenario will be adopted as one of the course of action in flood disaster risk reduction management since it has lower peak runoff flow and total runoff volume and longer lag time. Hence this study lends credence the significant role of adopting sound land use management in mitigating flood hazard.

ACKNOWLEDGEMENT

We are very grateful for the research funding and support given to us by DOST–PCIEERD; as well as to UP–Diliman LiDAR Team, GeoSAFER Program, MSU–Iligan Institute of Technology, NAMRIA, DENR and DPWH, Region 10, Philippines for making this study a success.

REFERENCES

[1] Iligan City Disaster Risk Reduction Management Council, 2013. Final Report on Typhoon Sendong (Washi), Iligan City, Philippines.
[2] Salcedo, Stephanie Mae B., Suson, Peter D. ,Milano, Alan E. and Ignacio, Ma. Teresa T. Impact of dynamically changing land cover on runoff process: The case of Iligan river basin. Unpublished.
[3] Taylor, Matthew, Mulbolland, Murray and Thomburrow, Danny, "Infiltration Characteristics of Soils Under Forestry and Agriculture in the Upper Waikato Catchment", 12 September 2008, http://www.waikatoregion.govt.nz/PageFiles/13347/Tr0918.pdf.
[4] Noordwijk, Meine Van and Verbist, Bruno, "Overstory # 104-Soil and Water Conservation", http://www.agroforestry.net/the-overstory/165-overstory-104-soil-and-water-conservation