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ORIGINAL RESEARCH PAPER

The impact of sound land use management to reduce runoff

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ABSTRACT

The study aimed to determine the impact of sound land use management to the runoff in Kabuntalan, Maguindanao in Tamontaka river basin. This was done through simulation and the comparison of the three land cover scenarios such as 2015 land cover, 2025 projected land cover and desired land use to determine its difference in terms of runoff. Hydrologic Engineering Center-Hydrologic Modeling System was used for simulating runoff. The geographic Information system was used for the preparation of the land use/cover and as an interface between GIS and HEC-HMS. Based on the result, 2025 land cover values in runoff volume and peak outflow increase from 2015 land cover while decrease in desired land use. There is shorter time to peak in 2025 land cover than desired land use. The 2025 land cover, represented the land cover without intervention, showed that agriculture will dominate the area with 78.28% of the total area, closed canopy forest and open forest cover will reduce with 4.57% and 6.78% of the total area respectively. The desired land use represented the sound land use management, showed that there will be 13.9% decreased in agriculture. This can, however, result to increase in close canopy forest (112.3%), grassland (125.7%), and open forest (4.3%). The study showed that desired land use will most likely reduce the magnitude of the flood than the 2015 and 2025 land covers. Thus, adopting sound land use management in Tamontaka river basin is crucial to reduce runoff and thereby mitigate flooding in the study area.

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INTRODUCTION

Flood is one of the most disastrous phenomena that can occur in an area since it has damaging impacts to human lives, properties, and infrastructures such as death, spread of diseases, and destruction of livelihood (Siddayao *et al.,* 2015). Floods are caused by natural events, by human activities, or by combinations of both and have the potential to injure fatally, displace a large number of people and cause damage to the environment. Irresponsible changes in land use/cover, especially those caused by human activities, are expected to increase runoff and thereby increase flood magnitude. The destruction of a protective land cover, such as the forest, contributed to the frequent and massive flooding in the area. To overcome the water related problems, extensive care should be given to the operation and management of reservoirs and watersheds. But in many cases, poor land use planning and land management practices during rapid development have adversely impacted the surface runoff quantities and quality through the reduction of land cover, loss of plant nutrients, deterioration of river water quality and an increase of impervious surface area (Udhavrao, 2014). Hence, proper land use management plays a key role in mitigating flooding by reducing runoff which is the major source of flood waters. Like the rest of the world, the Philippines is not exempted from this hydrological hazard. In particular, Kabuntalan is known to be one of the flood-prone municipalities in southern Philippines. Every year during rainy season, the municipality experiences severe flooding affecting most of the barangays within the area. In July 25, 2013, flood occurred in the municipality due to frequent rains caused by Low Pressure Area (LPA) and Inter Tropical Convergence Zone (ITCZ). According to the annual report of the National Disaster Risk Reduction and Management Council (NDRRMC), it showed that the total affected population was approximately 49,615 families or 247,428 persons for the five municipalities in Maguindanao province (NDRRMC, 2013). In June 13, 2014, another flooding incident affected more than ten municipalities in Maguindanao province (NDRRMC, 2014). In July 2015, another flood incident was also reported by NDRRMC affecting eight Municipalities of the same province. Updated assessment shows that the affected population was estimated at 13,020 families or 62,929 persons for the 82 barangays of Region VII, X, and ARMM of which, 102 families or 510 persons were evacuated (NDRRMC, 2015). Several studies have been conducted using the Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS model) in different countries under different soil and climatic conditions. Hammouri and Naqa, 2007 modeled the rainfall-runoff process using HEC-HMS and GIS in a selected ungauged basin for the purpose of groundwater artificial recharge at Zarqa catchment, Jordan. Chu and Stenman, 2009 used HEC-HMS model for both event and continuous hydrological modeling in Monalack watershed in west Michigan. HEC-HMS model has been also used to simulate rainfall-runoff process with geo-informatics and atmospheric models for flood forecasting and early warnings in different regions of the world (Abed *et al.,* 2005; Anderson *et al.,* 2002; Clay *et al.,* 2005; Hu *et al.,* 2006; Knebl *et al.,* 2005; McColl and Aggett, 2006; Yusop *et al.,* 2007; Yener *et al.,* 2012; Arekhi, 2012; Majidi and Shahedi, 2012; Halwatura and Najjim, 2013; Ali *et al.,* 2011; Dzubakova, 2010). It was also used for watershed management in different parts of India (Putty and Prasad, 2000; Bhatt *et al.,* 2012). In the Philippines, HEC-HMS was also used for flood simulation in different major river basins of the country such as Iligan, Mandulog, Cagayan and Marikina river basins (Milano *et al.,* 2016a; Milano *et al.*, 2016b; Benavidez *et al.,* 2016; Brebante, 2017). HEC-HMS has been applied successfully since more than 30 years and is accepted for many official purposes such as the determination of floodways for the U.S. Federal Emergency Management Agency (HEC, 2000). The model was found accurate in spatially and temporally predicting watershed response in event based and continuous simulation (Choudhari, 2014). There are also several related studies which prove the land use/cover changes affects the flood and thus land use management plays vital role in mitigating flood. Kabanda *et al.*, 2013 concluded in his study that the changes in land cover has resulted more to the increase of river discharge than climatic changes although both these changes have occurred together to have an even greater impact than if each were acting alone. Brebante, 2017 found out that land cover changes have influence to flashflood in the river basin. Archer *et al.,* 2010 noted that the rates of change in discharge appear to respond to land use changes and thus provide a potential basis for application to land use management policies.

Leach, 2015 also concluded that the land cover changes do play an important role in the changes of the observed hydrologic response. Precipitation also plays a role, but not to the extent exhibited by changes to land cover. Since land cover change is a major contributor and primarily caused by human activity, there are ways of preventing increased stream flow and runoff. Prevention may include Best Management Practice, or returning some agricultural land back to grassland, forest lands, or native prairie vegetation. Bingwa, 2013 also stated in his study that better land management can decrease river flow and mitigate flooding risks. The main objective of this study was to determine the impact of sound land use management to runoff in Kabuntalan, Maguindanao in Southern part of the Philippines in Tamontaka river basin. It also aimed to determine the change of past land covers and relate its impact on the runoff in the study area. Further, this study was intended to serve as baseline data of the LGU's and other concerned authorities in decision-making to mitigate flooding in their respective area. This study was done to measure the amount of runoff reduced as a result of employing a sound land use approach—which in this study is termed as the desired land use and was then compared to two land cover scenarios, one of which is the latest available land cover and the other is a future land cover scenario wherein irresponsible logging and inappropriate land uses remain unabated.

MATERIALS AND METHODS

Study area

The study area was undertaken in the Tamontaka river basin inside Kabuntalan Municipality, Province of Maguindanao, BARMM in 2018. The municipality has an approximate area of 10,149 hectares (ha), with a 07˚ 07' 12" N latitude and 124˚ 21' 51" E longitude. It is situated 140-km away from the Provincial Capital of Buluan, Maguindanao and 22-km from Cotabato City at the northern side and on the southern side is the Tamontaka River, which is one of the twenty sub-basins of Mindanao River Basin (MRB), second largest river basin in the Philippines, with the lowest elevation of -0.46m as attributed by its geographic location (RBCO, 2012). Thus, MRB drains towards Illana Bay through Tamontaka River in Cotabato City. Geographically, Kabuntalan is bounded on the north by the town of Northern Kabuntalan, on the south by the Municipality of Datu Odin Sinsuat, on the east by the Municipality of Datu Piang, while on the west by the City of Cotabato. Generally, the Kabuntalan

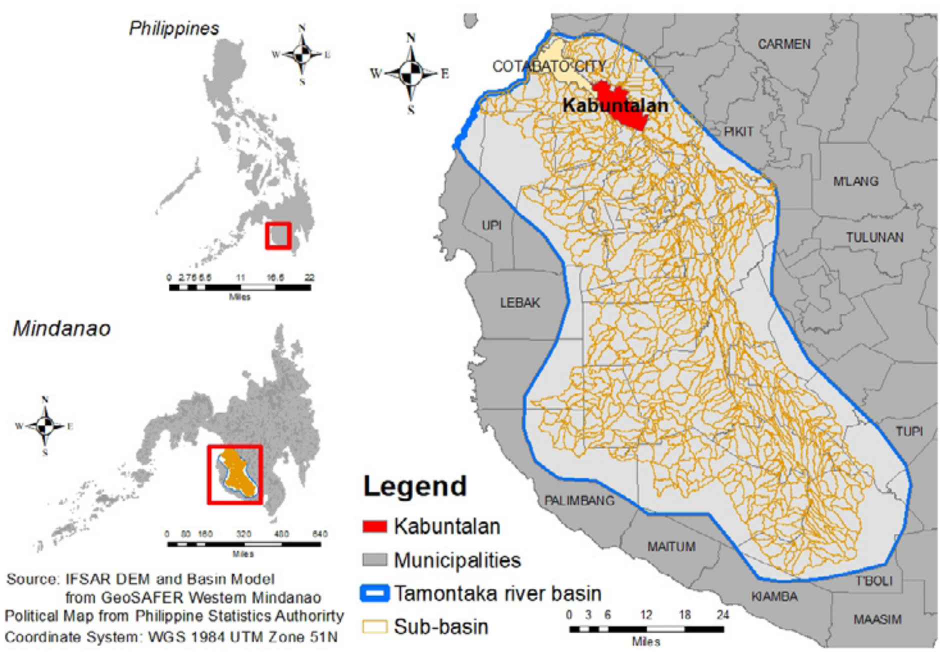


Fig. 1: Location Map of the study area

enjoys a favorable climate throughout the year. The dry season begins at January until May, while the wet season begins on July until October. Its land capability is usually depended on the seasonal over flowing of the rivers. Majority of the area are wet lands and becomes unproductive during rainy season. However, it is estimated that about 2,538.92 ha are good enough for lowland rice and about 2,747.60 ha more can be planted with diversified crops provided there are available quality crops and proper timing is done.

Rainfall data

Table 1 shows the annual maximum 24-hour from General Santos RIDF rain gage station recorded by PAGASA, the National Weather Bureau of the Philippines. Rainfall data were generated for simulating the hydrologic processes in the study area to evaluate its response to different intensities of various rainfall return period. Utilization of rainfall period in HEC-HMS model may contribute largely to land use management. In this study, 5, 10, 25, 50, and 100-Year (y) RRP were generated using RIDF relationships based on 31 years of rainfall record in General Santos rain gage station (Fig. 2).

Soil characteristics data

The municipality of Kabuntalan has 17 barangays and has a total land area of 10,149 ha which consist of four types of soil. These are undifferential soil, hydro soil, Tamontaka clay loam, and marshy soil.

Table 1. 24-hour RIDF data from General Santos rain gage station (PAGASA, 2019)

Computed extreme values precipitation (mm)								
T (yrs)	5mins	15mins	1h	2h	3h	6h	12h	24h
5y	8.3	16.4	32.5	47.1	56.6	74	90.4	102.7
10y	10	19.7	39.7	56.8	68.4	89.8	109.9	125.1
25y	12.1	23.9	47.4	69.1	83.4	109.8	134.5	153.4
50y	13.7	27	53.6	78.2	94.5	124.7	152.8	174.3
100y	15.3	30.1	59.8	87.2	105.5	139.4	170.9	195.2
Equivalent average intensity of computed extreme values (mm/h)								
T (yrs)	5mins	15mins	1h	2h	3h	6h	12h	24h
5y	99.6	65.6	32.5	23.6	18.9	12.3	7.5	4.3
10y	120.0	78.8	39.7	28.4	22.8	15.0	9.2	5.2
25y	145.2	95.6	47.4	34.6	27.8	18.3	11.2	6.4
50y	164.4	108.0	53.6	39.1	31.5	20.8	12.7	7.3
100y	183.6	120.4	59.8	43.6	35.2	23.2	14.2	8.1

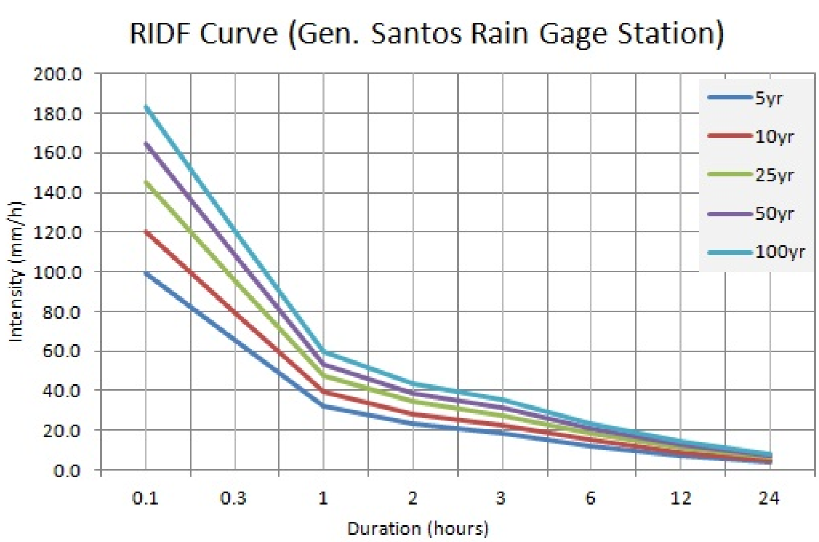


Fig. 2: Rainfall Intensity Duration Frequency curves of General Santos rain gage station

Undifferential soil is the most dominant areas in Kabuntalan which comprised of 8,626.65 ha or 85% of the total land area, followed by clay loam with 1,025.05 or 10.1%, hydro-soil with 284.17 or 2.8% and the marshy soil with 213.13 or 2.1% of the total land area.

Climatic condition

Based on the Philippine climate, Kabuntalan has a tropical climate. There is a great deal of rainfall in the area, even in the driest month. Its average annual temperature is 27.4 °C while the average annual rainfall is 2058 mm. The least amount of rainfall occurs in January. While the greatest amount of precipitation occurs in October, with an average of 253 mm. The dry season begins at January until May, while the wet season begins on July until October. The temperatures are highest on average in April, at around 28.1°C. The lowest average temperatures in the year occur in January, when it is around 27.0°C.

Land use/cover pattern

Kabuntalan is an agri-fishery area wherein farming and fishing are the main source of livelihood. The land use/cover pattern of Kabuntalan area is characterized mostly by agricultural lands, grasslands, marshlands, residential areas and roads. Main activity of the area is agriculture, which generates income for the farmers. Agricultural activities include paddy cultivation, fish production, vegetables, and so on. However, most of the farmers produce rice; others are corn, coconut, mango and banana while some of them have fishponds, which support their income fully or partly.

Land classification

Based on the land classification, the municipality has an area of 522.5602 ha of alienable and disposable lands and an estimated forestland of 9,626.4731 ha which the existing land uses are combination of agriculture, residential, and other uses from the total land area of 10,149 ha. Since Kabuntalan is surrounded by bodies of water, its land capability is usually depended on the seasonal over flowing of the rivers. Majority of the area are wet lands and becomes unproductive during rainy season. However, it is estimated that about 2,538.92 ha are good enough for lowland rice and about 2,747.60 ha more can be planted with diversified crops provided there are available quality crops and proper timing is done.

Relationship between land use/cover and runoff

Land use/cover changes have a bearing on the relationship existing between rainfall and runoff and the relationship between overland runoff and sediment yield. This alters the rate of soil erosion and water loss (Kim *et al.,* 2002). The main driving forces behind flooding are changes in land use activities in flood and coastal plains, increased population resulting in increased urbanization and settlements and increased infrastructure such as roads and railway lines. Conversion of natural land to cultivated land often means reclamation of wetlands and clearance of native vegetation (Mustard *et al.,* 2004). According to Farley *et al.,* 2005 in a study established that the conversion from natural vegetation to croplands led to increased magnitudes in flooding in watersheds. The type and amount of vegetation cover affects the amount of water that ends up in a drainage basin (Farley *et al.,* 2005). Deforestation results in increased runoff and often a decrease in river channels' capacity due to increased sedimentation rates (Mustard *et al.,* 2004). Litter and leaves usually scattered under the forest canopy play an important role in holding water, and allowing evenly distributed infiltration of water into the soil. Plant canopies and litter intercept raindrops, reducing some of the intensity associated with the rainfall (Yahaya *et al.,* 2010).

Applied methodology

In this study, three land cover scenarios such as the 2015 Land Cover, which is the latest available land cover; 2025 Projected Land Cover, which is the condition by which irresponsible logging and inappropriate land uses remain unabated; and Desired Land Use, wherein sound land use is employed. These three land cover scenarios were simulated for runoff and were then compared to determine their difference in output such as runoff volume, peak outflow, and lag time using rainfall return periods of 5, 10, 25, 50, and 100-year. The 2015 Land Cover, which is the existing land cover in the river basin, served as the baseline of the study. The 2025 Projected Land Cover, represented the land cover without intervention and was done through correlation approach using trend analysis function from Microsoft Excel derived from past land cover satellite images such as 2003, 2010, and

2015 land cover; while the Desired Land Use makes use of the sound land use management through simulation using slope as the basis in assigning different land uses. These slopes were categorized into agriculture (0–18% slope), agroforestry (18–30% slope), production forest (30–50% slope), and protection forest (>50% slope). The slope raster file was derived from an integrated Digital Elevation Model (DEM) which is mostly of the Interferometric Synthetic Aperture Radar (IFSAR) with a resolution of 5m, but it was integrated with the limitedly available Light Detection and Ranging-Digital Elevation Model (LiDAR-DEM) with a resolution of 1m to produce a more detailed slope geospatial data (Milano *et al.,* 2016a). Fig. 3 below shows the map of study area derived from IFSAR DEM.

The ArcGIS (Geographic Information System) 10.2 version was used for the preparation of the 2025 Land Cover and the Desired Land Use and also as an interface between the GIS and HEC-HMS. The HEC-HMS was used for simulating runoff models based on a combination of the SCS Curve Number model, the Clark Unit Hydrograph model, Recession baseflow model, and the Muskingum-Cunge flow routing model. The three land cover scenarios were set ready through intersecting land cover with another available geospatial vector file called Soil Hydrological Group. After intersection, these were fed into the HEC-GeoHMS (Hydrologic Engineering Center-Geospatial Hydrologic Modeling System) an extension of the ArcGIS for basin model and initial preparation of the parameters. Once the basin model is ready, the HEC-HMS was used for simulating the runoff of the three land cover scenarios (Geo-SAFER, 2019).

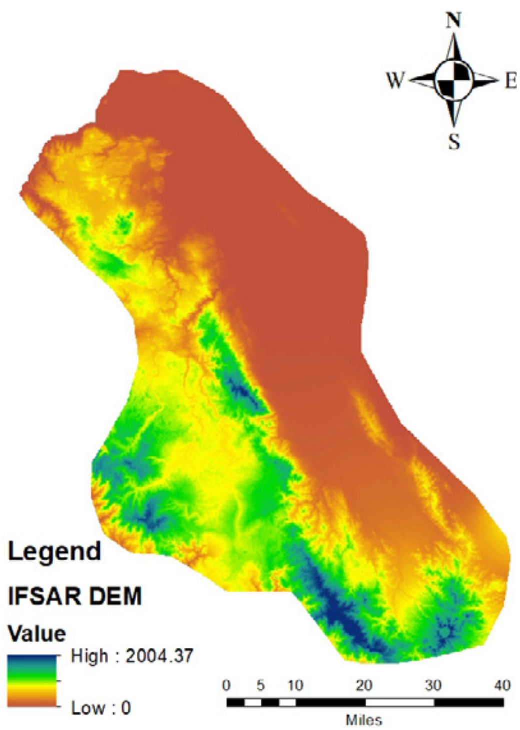


Fig. 3: IFSAR DEM of the study area

Trend analysis using excel

Trend or Trendline analysis, a built-in analysis tool in excel, is a linear least squares regression tool that can be employed to provide some correlation to data points that are seemingly not linked at all. It uses historical experiences to project, or estimate, future experiences. Trend analysis methods have been developed for climate change study (Yin, 2014). There are several types of Trendline correlation functions such as linear fit, logarithmic fit, polynomial fit, with varying degree (2-6), power fit, exponential fit and moving average fit, with varying period (2-15). The accuracy of the fit can be interpreted using the R-squared value. As the R-squared value approaches 1, the accuracy of the fit approaches 100% which applied in this study. This analysis gives the best fit line that provides a reasonable approximation of the line connecting the data points. In this study the data points used were the past land covers in 2003, 2010 and 2015 in ha (Table 2). Its primary purpose is to forecast future of land cover which the 2025 Projected Land Cover (Table 3).

RESULTS AND DISCUSSION

Land cover in 2003, 2010 and 2015

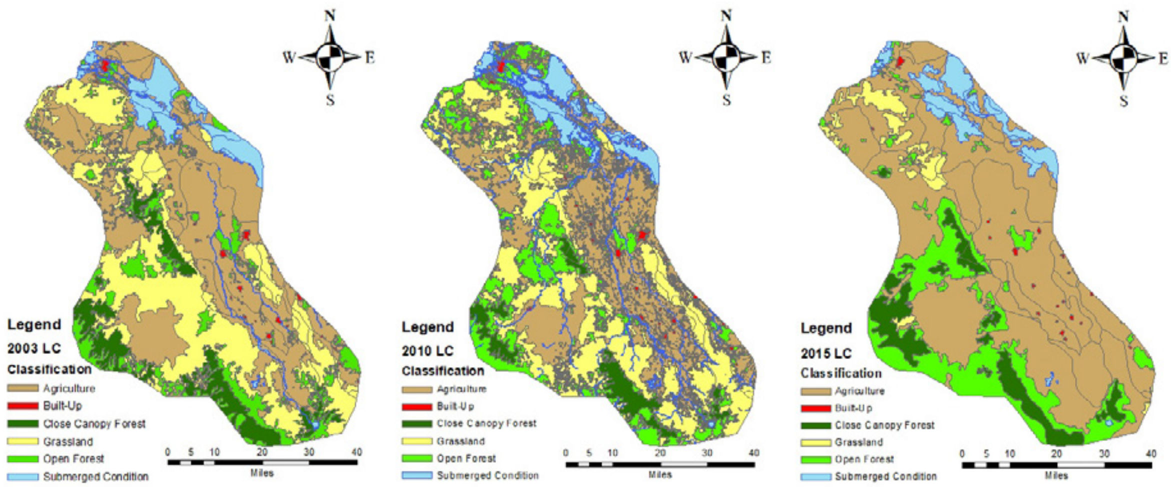
The Table 2 shows the changes of the areas per land cover classification in the study area. While Figs. 4 and 5 show the change of land cover visual images geographically and graphically. Much of the changes are on the Agriculture and Open Forest areas. For example, the agriculture area in 2003 is 355, 394.85 ha or 42.62% of the total 833, 878 ha. This was reduced to 298,682.90 or 35.82% in 2010. However, agriculture area was almost doubled in 2015 covering 536, 55.31 or 65.34% of the total area. While agriculture area for production increased, there was continuous reduction of areas classified as Open Forest. In 2003, Open Forest areas was 297, 874.83 or

Table 2. Land cover proportion of 2003, 2010 and 2015 (Namria and Geo-SAFER, 2019)

Land Cover Classification	2003 LC (ha)	%	2010 LC (ha)	%	2015 LC (ha)	%
Agriculture	355,394.85	42.62	298,682.90	35.82	536,550.31	64.34
Built-Up	5,976.08	0.72	14,423.92	1.73	2,817.97	0.338
Close Canopy Forest	76,652.36	9.19	41,916.72	5.03	68,198.83	8.18
Grassland	58,073.92	6.96	254,691.42	30.54	33,526.92	4.02
Open Forest	297,874.83	35.72	167,336.78	20.07	142,622.23	17.10
Submerged Condition	39,905.96	4.79	56,826.26	6.81	50,161.74	6.02
Total (ha)	833,878.00	100%	833,878.00	100%	833,878.00	100%

Table 3: Land cover classification of the projected land cover in 2025 in ha

Land Cover Classification	2015	%	Projected Land Cover in 2025	%	% Change (2015 to 2025)
Agriculture	536,550.31	64.34	652,744	78.28	22%
Built-Up	2,817.97	0.338	527.17	0.06	-81%
Close Canopy Forest *(Protection Forest)*	68,198.83	8.18	38,134.2	4.57	-44%
Grassland *(Agroforestry)*	33,526.92	4.02	8,418.83	1.01	-75%
Open Forest *(Production Forest)*	142,622.23	17.10	56,508.6	6.78	-60%
Submerged Condition	50,161.74	6.02	77,545.2	9.30	55%
Total (ha)	833,878.00	100%	833,878.00	100%	



a. 2003 Land Cover: generated using Landsat 7 ETM imageries

b. 2010 Land Cover: generated using Alos/avnir 2, SPOT 5 and Landsat 7

c. 2015 Land Cover: generated from 30-m resolution Landsat 8 imageries

Fig. 4: a) 2003 land cover; b) 2010 land cover; and c) 2015 land cover

35.72% of the total land area, reduced to 20.07% in 2010 and further reduced to 17.10%. These changes show that more areas are used for food production which resulted to reduction of open forest cover, among others. This resulted to more flooding. Table 2 even shows that the submerged condition in the study area increased from only 39,905.96 ha in 2003 to 50, 161.74 in 2015. The observation in the study area is also true in the Philippines. Forest cover in the Philippines has declined continuously by an average of 150,000 ha per year (Lasco and Pulhin, 2009), decreasing from the estimated 27.5 million ha in 1900

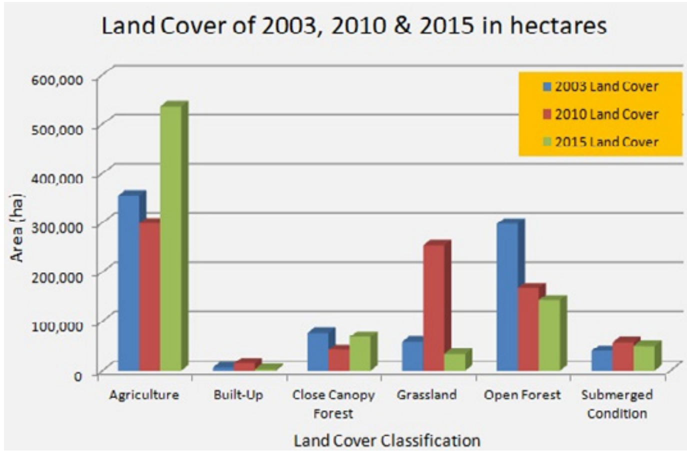


Fig. 5: Land cover of 2003, 2010 and 2015 in ha

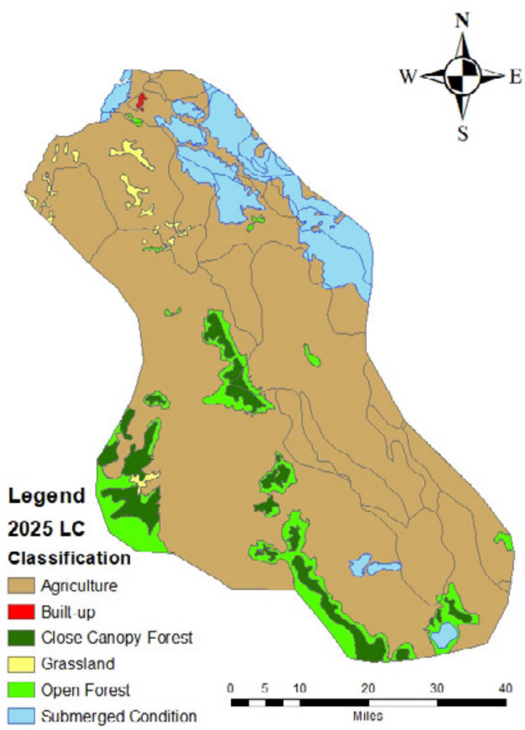


Fig. 6: Map of 2025 Projected Land Cover

to only 6.7 million ha in 1990 (DENR, 2013). This trend of land use management may create bigger problem in the future. The destruction of the forests threatens watersheds that can result to massive soil erosion, declining soil fertility, and sedimentation of rivers and its tributaries. This can cause severe flooding during rainy seasons (Paragas *et al.,* 1997). The 2003 land cover comes from the USAID Eco-Governance Project while the 2010 and 2015 was sourced out from National Mapping and Resource Information Authority (NAMRIA) in a shapefile format.

Projected Land Cover in 2025

Table 3 shows the comparison of the latest land cover data and the 2025 land cover projection. The 2025 Projected Land Cover is the projection if the land use is continued without intervention. Projection was done through correlation approach using trend analysis function from past land cover satellite images such as 2003, 2010, and 2015 land cover. Comparing the latest land cover (2015) and the projected land cover (2025), and if the current land use management will continue, there will be at least 22% increase in the agriculture area. The practice, however, would result to decrease in built-up areas (81%), decrease in close canopy forest (44%), and grassland (75%). With the current Land use management, the open forest will be affected in 2025 which could result to 60% decrease. This means that the 142, 622.23 ha open forest in 2015 will be only 56, 508.6 ha in 2025. There are projections that unless the destruction of forests is halted, most will have gone or been severely damaged in just 21 years (Paragas *et al.,* 1997). The scenario also shows that the situation could be worse since the submerged condition will have increases from only 6.02% of the total area in 2015 to 55% of the total land area in 2025. Submerged conditions are flooded. Floods cause serious damage to production areas and major infrastructures such as roads, bridges, and irrigation dikes. Most of the typhoon-induced flash floods and landslides are caused by large scale deforestation, many through illegal logging, mining and shifting cultivation. Several studies have shown that changes in land cover have negative impacts on the hydrological and hydraulic processes in river basins. Anthropogenic activities such as deforestation, urbanization, and croplands expansions can change how a river basin responds to rainfall (Isik *et al.,* 2008). It has been found to increase surface runoff and peak flows (Koneti *et al.*, 2018, Guzha *et al.*, 2018). A comparison of 1995 and 2017 land use data in Butuan, Philippines (Santillan *et al.,* 2019) also revealed the same. It has found out that Agusan river basin is 67.7% forest in 1995 but had decreased to 62.8% in 2017. Agricultural areas in the basin were also found to have increased from 12.2% to 15.5% in the same period. Fig. 6 shows the map of the 2025 Projected Land Cover.

Desired land use

Table 4 shows the comparison between the 2015

Table 4: Proportion and area of the desired land use

Land Cover Classification	2015	%	Desired Land Use (DLU)	%	% Change (2015 to DLU)
Agriculture	536,550.31	64.34	461,841.69	55.38	-13.92%
Built-Up	2,817.97	0.338	2,795.00	0.335	-0.82%
Close Canopy Forest *(Protection Forest)*	68,198.83	8.18	144,786.49	17.36	112.30%
Grassland *(Agroforestry)*	33,526.92	4.02	75,656.27	9.07	125.66%
Open Forest *(Production Forest)*	142,622.23	17.10	148,798.55	17.84	4.33%
Submerged Condition	50,161.74	6.02	-	-	0%
Total (ha)	833,878.00	100%	833,878.00	100%	

Table 5: Result of simulation from different parameters at Nth year rainfall return period using HEC-HMS

Parameters at Nth year rainfall return period (RRP)	2015 land cover	Projected land cover	Desired land use
5-y RRP			
Total Rainfall (mm/day)	102.7	102.7	102.7
Total Runoff Volume (m^3/day)	49,732.8	52,470.1	48,093
Peak Rainfall (mm)	12.7	12.7	12.7
Peak Outflow (m^3/s)	1,341	1,477.1	1,203.8
Time to Peak (rise time)	1h 30min	1h 10min	7h 40min
10-y RRP			
Total Rainfall (mm/day)	125.1	125.1	125.1
Total Runoff Volume (m^3/day)	66,492.6	70,617.6	63,407.5
Peak Rainfall (mm)	15.3	15.3	15.3
Peak Outflow (m^3/s)	2,033.7	2,245.3	1,828.8
Time to Peak (rise time)	1h 10min	1h	6h 50min
25-y RRP			
Total Rainfall (mm/day)	153.4	153.4	153.4
Total Runoff Volume (m^3/day)	90,407.2	96,423.7	85,330.2
Peak Rainfall (mm)	18.5	18.5	18.5
Peak Outflow (m^3/s)	3,048.5	3,350.1	2,720.6
Time to Peak (rise time)	1h	50min	6h
50-y RRP			
Total Rainfall (mm/day)	174.3	174.3	174.3
Total Runoff Volume (m^3/day)	110,091.9	117,582.9	103,298.6
Peak Rainfall (mm)	20.9	20.9	20.9
Peak Outflow (m^3/s)	3,876.6	4,227.7	3,461.4
Time to Peak (rise time)	1h	40min	5h 30min
100-y RRP			
Total Rainfall (mm/day)	195.2	195.2	195.2
Total Runoff Volume (m^3/day)	131,813.7	140,818.4	123,189
Peak Rainfall (mm)	23.3	23.3	23.3
Peak Outflow (m^3/s)	4,760.6	5,151.3	4,275.3
Time to Peak (rise time)	50min	40min	5h

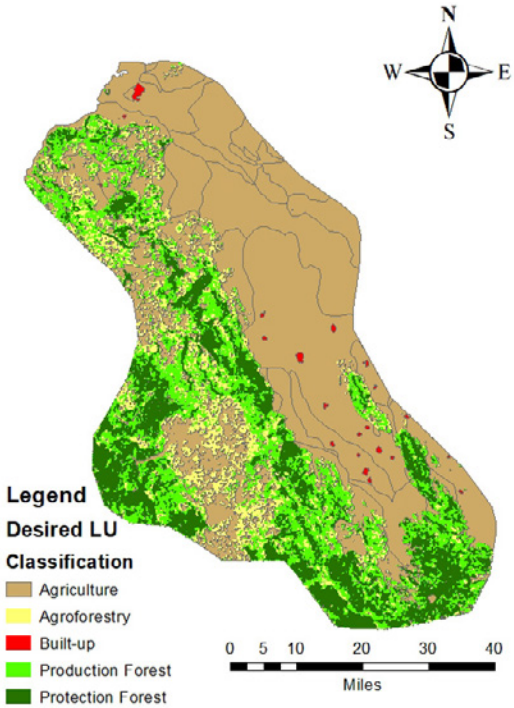


Fig. 7: Map of Desired Land Use

Land Cover and the Desired Land Use. If the Desired Land Use Management is followed, there will be 13.9 % decreased in the areas for agriculture. This can, however, result to increase in close canopy forest (112.3%), grassland (125.7%), and open forest (4.3%). According to Leach, 2015 best management practice or returning some agricultural land back to grassland, forest lands, or native prairie vegetation may prevent increase stream flow. This means that there will be more protection of the soil from siltation and erosion and thereby prevent massive flooding. Larger forest area leads to lower surface runoff as more forest cover tended to improve infiltration (Arceo *et al.*, 2018). In addition, the presence of Agroforestry—which allows the combination of food production and soil and water conservation—bolsters the protection of soil from siltation and erosion. JICA, 2016 report shows that in Maguindanao, heavy erosion and siltation is seen as cause of flooding. Erosion is likely to occur due to the steep slope, no vegetation, and poorly consolidated or compacted sediments in the Mindanao River Basin. Sediment is transported downstream and makes shallow the river beds. It is desired that there will be no submerged areas. Fig. 7 shows the map of the desired land use. Though the desired land use can protect land cover, and reduce flooding, it can have effect on the production of food since agriculture land is decreased. Without better technology to produce more in the same farm area, shortage of food products could be one of consequences when agriculture area is reduced.

Runoff simulation of 2015, 2025 land cover and desired land use

Table 5 and Fig. 8a–e below show the result of runoff simulation of the current land cover (2015), projected land cover (2025) and the desired land use. Based on the result, it can be observed that there are different values yielded between 2025 land cover

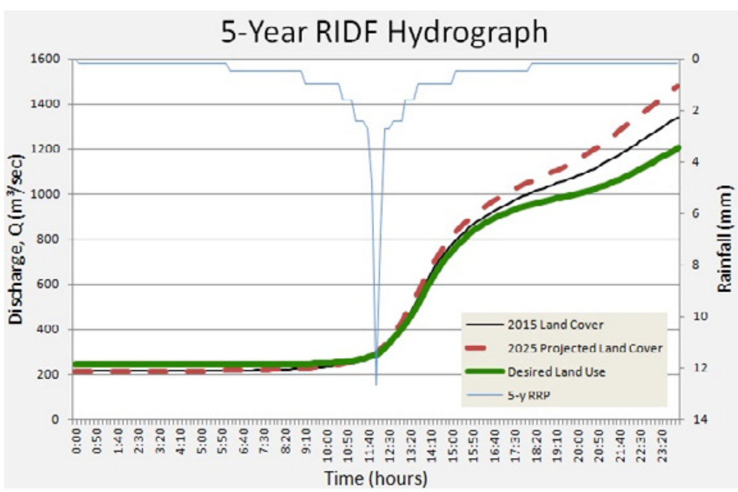


Fig. 8a) 5-Year RIDF hydrograph for simulated land covers

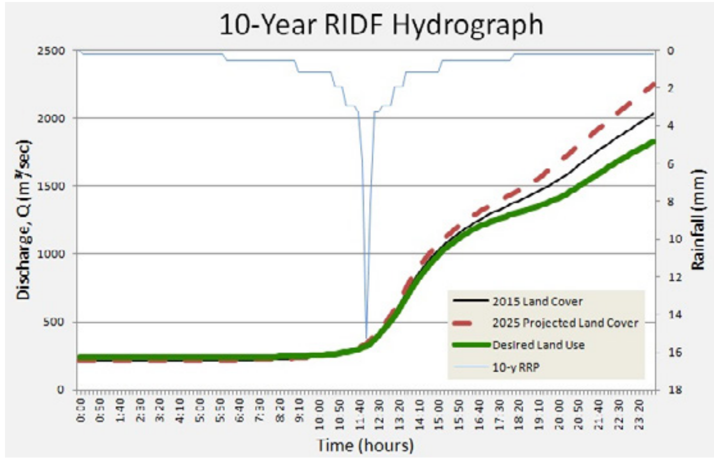


Fig. 8b) 10-Year RIDF hydrograph for simulated land covers

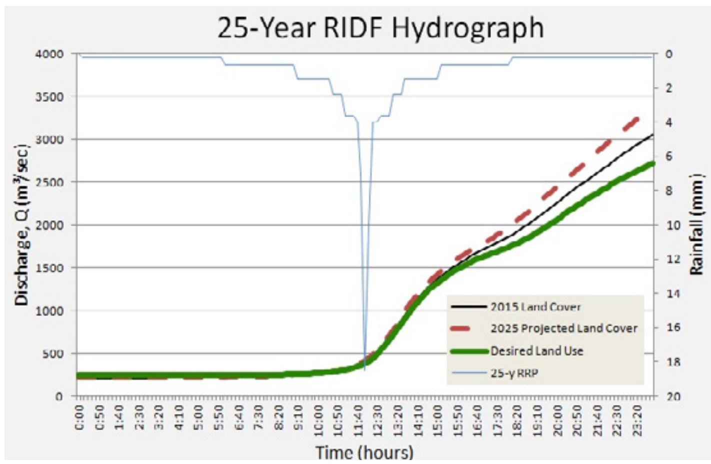


Fig. 8c) 25-Year RIDF hydrograph for simulated land covers

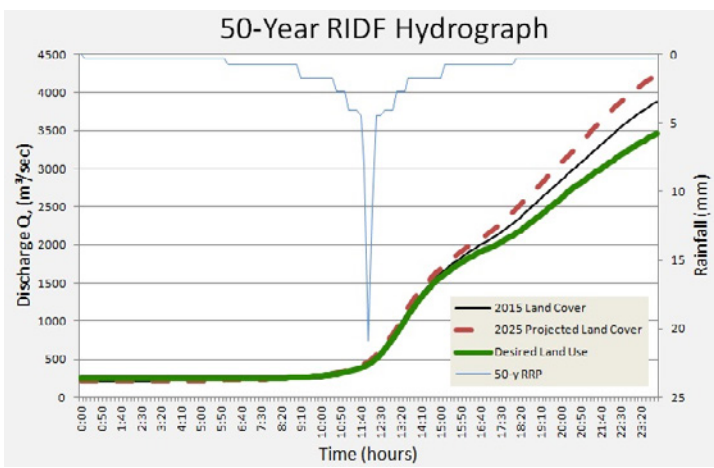


Fig. 8d) 50-Year RIDF hydrograph for simulated land covers

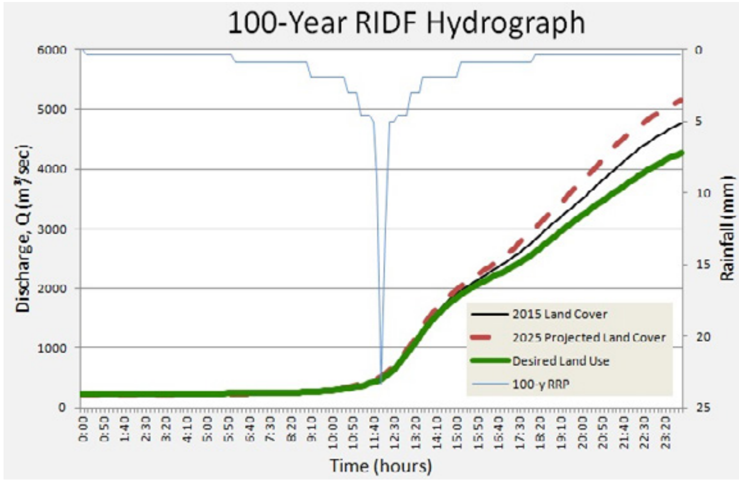


Fig. 8e) 100-Year RIDF hydrograph for simulated land covers

and desired land use as compared to 2015 land cover. In 2025 land cover all values in runoff volume and peak outflow increase from 2015 land cover while decrease in desired land use. The time to peak has shorter time in 2025 land cover than desired land use. For example, in 5-year RRP the runoff volume in 2015 land cover is 49,732.8 m^3/day. This value will increase in 2025 land cover to 52,470.1 m^3/day while reduce in desired land use to 48,093 m^3/day. Moreover, the peak outflow in 2015 land cover is 1,341 m^3/s which will increase in 2025 land cover to 1,477.1 m^3/s and reduce in desired land use to 1,203.8 m^3/s. For the peak time, in 2015 it has 1h 30min and it will reduce in 2025 land cover to 1h 10min and increase to 7h 30min in desired land use. This indicates that there will be longer flood preparation in desired land use before the arrival of flood to the study area than projected land cover. Comparing to the projected land cover, the Desired Land Use in all different RRP yielded to smaller runoff volume, lower peak outflow, and longer lag time (time to prepare before the arrival of the flood) from 2015 land cover (Table 5). This means that the Desired Land Use will most likely mitigate flooding since reduction in runoff means a reduction in flood magnitude as runoff is the major source for flooding. The reason for this is because the Desired Land Use has a substantial presence of the Production and Protection Forest vegetation than the 2015 Land Cover and the 2025 Projected Land Cover. Furthermore, with the presence of Agroforestry in the Desired Land Use, all these create a condition where protection of the soil from erosion will reduce runoff and siltation—the very hydrological processes that influence flooding. The total rainfall was derived from computed extreme values precipitation in Table 1 while peak rainfall was based on the computed highest values of incremental precipitation occurred in every return period. Runoff volume, peak outflow and time to peak were generated from the summary results of rainfall-runoff model or HEC-HMS simulation in the depth gage junction.

CONCLUSION

The study aimed to determine the impact of sound land use management to reduce runoff in the study area. The study used hypothetical flood scenarios based on the rainfall events gathered by PAGASA, the National Weather Bureau of the Philippines. The study generated the attribution data of past land cover satellite images in 2003, 2010 and 2015 derived from NAMRIA which explained the changes in values of land cover classifications using GIS. Much of the changes are on the Agriculture and Open Forest areas which showed that more areas are used for food production which resulted to reduction of open forest cover, among others. With the absence of forest cover, there is a negative impact on the occurrence of massive flooding in the study area. The 2025 land cover, represented the land cover without intervention, was projected through correlation approach using trend analysis function from Microsoft Excel. If the current land use management will continue, the agriculture land cover will dominate the area with 78.28% of the total area, close canopy forest and open forest cover will reduce with 4.57% and 6.78% of the total area respectively. The destruction of forest especially in the upstream level contributed to massive flooding in the area. The scenario also showed that the situation could be worse since the submerged condition will also increase. Consequently, the status of the 2025 land cover and onwards are expected to be a threatening since the values of runoff volume and peak outflow are increasing and the lag time is decreasing. This indicates an immediate intervention of the authorities and experts to reduce flood in the study area. The Desired Land Use, represented the sound land use management, was done through simulation using slope as the basis in assigning different land uses. If the Desired Land Use Management is followed, there will be 13.9% decreased in the areas for agriculture. This can, however, result to increase in close canopy forest (112.3%), grassland (125.7%), and open forest (4.3%). This means that there will be more protection of the soil from siltation and erosion and thereby prevent massive flooding. The study also showed that Desired Land Use will most likely reduce the magnitude of the flood since its simulated runoff parameters yielded to smaller runoff volume, lower peak outflow, and longer lag time (time to prepare before the arrival of the flood) than the 2015 Land Cover and 2025 Land Cover. Therefore, the adoption of a Sound Land Use Management is highly recommended as one of the means to mitigate flood. The LGU's and other concerned agencies need to immediately conduct flood mitigation program to reduce the increase of floods in the study area.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

ABBREVIATIONS

°C	Degree Celsius
%	Percent
ARMM	Autonomous Region in Muslim Mindanao
BARMM	Bangsamoro Autonomous Region in Muslim Mindanao
CLUP	Comprehensive land use plan
DEM	Digital elevation model
DENR	Department of Environment and Natural Resources
DOST–ERD	Department of Science and Technology – Engineering Research and Development for Technology
DOST–PCIEERD	Department of Science and Technology – Philippine Council for Industry, Energy, and Emerging Technology Research and Development
FDC	Forestry Development Centre
Geo-SAF-ER	Geo-Informatics for the Systematic Assess-ment of Flood Effects and Risks Towards a Resilient
GIS	Geographic information system
GSE	Graduate School for Engineering
h	Hour
ha	Hectares
HEC	Hydrologic Engineering Center
HEC-GeoHMS	Hydrologic Engineering Center-Geospatial Hydrologic Modeling System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
IFSAR	Interferometric Synthetic Aperture Radar

ITCZ	Inter Tropical Convergence Zone
JICA	Japan International Cooperation Agency
LC	Land cover
LGU	Local Government Unit
LiDAR	Light detection and ranging
LPA	Low pressure area
LU	Land use
m	Meter
min	Minutes
mm	Millimeter
MRB	Mindanao River Basin
MSU–IIT	Mindanao State University – Iligan Institute of Technology
NAMRIA	National Mapping and Resource Information Authority
NDRRMC	National Disaster Risk Reduction and Management Council
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PSA	Philippine Statistics Authority
RBCO	River Basin Control Office
RIDF	Rainfall Intensity Duration Frequency
RRP	Rainfall return period
S	Second
UPLB-CF-NR	University of the Philippines Los Banos-College of Forestry and Natural Resources
USAID	United States Agency for International Development
USACE	United States Army Corps of Engineers
UTM	Universal Transverse Mercator
WGS	World Geodetic System
Y	Year

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