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Flood risk analysis in Sg. Sam, Kuala Krai, Kelantan using remote sensing and GIS technique

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Flood risk analysis in Sg. Sam, Kuala Krai, Kelantan using remote sensing and GIS technique

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Abstract. In Malaysia, flood hazard is commonly occurred due to the geographical characteristic of the country. It is caused by an abundance of rains during the monsoon seasons and convection rains during the hot but humid periods. There is high demand in current trend and future scenarios of flood risks for accurate spatial and temporal information on the potential hazards and risks of flood especially in Kelantan as the state has been affected by floods annually. The research was conducted at Sungai Sam, Kuala Krai, Kelantan and the study area covers about 25 km². The objectives of the research are to produce flood risk area map covers during the worst flood event occurred on December 2014 of Sg. Sam, Kuala Krai, Kelantan and to correlate flood risk area map with land cover changes. In order to achieve objectives, the integrated of spatial technology of remote sensing and Geographical Information System (GIS) were used as tools. As a result, the flood risk area map consists of particular level has been successfully produced based on a few parameters such as accuracy of Digital Elevation Model (DEM), water level, flood depth and amounts of rainfall. Landsat images of pre-flooding and post-flooding were obtained to analyse the flood occurrence. Flood risk analysis is made by correlating flood risk area (low, medium and high) with land cover changes. The flood risk map produced clearly shows the spatial distribution of the flooded area which is located at areas with relatively low relief. The result showed that the significant decrease of plantation area has occurred in high and medium risk zone while land use at low risk zone was affected by urbanization process. Thus, integration of GIS coupled with terrain model and remotely sensed data can produce flood risk map with good accuracy.

Keywords: accuracy, DEM, flood risk, GIS

1. Introduction

A scientific flood risk management is used widely for reducing the economic loss which is usually associated with flood and waterlogging. It is because, an essential information containing strategy development and planning adaptation are provided by a reasonable flood risk analysis [1]. Details information in term of depth of flooding, probability of flooding and other flooding characteristics in grid datasets form is one of the ways that can be taken to reduce the flood risk. It is due to the term risk itself which is defined as the total of expected losses and damage of any type due to particular natural phenomenon.

The dimensions of the elements in an urban area suffered from floods shows the quantification of the damages and estimation of flood risk is more reliable if bigger areas of land are taken as the elements of the system [2]. The scenarios of floods are formulated as high, medium and low probability according to paradigm shift in the studies of floods. According to [3], an acceptable result of flood risk map is based on input parameters, historical as well as recorded flood data.

GIS plays an important role as good medium to carry out the studies that related to disaster management. Preparedness initiatives can reduce the impact of disasters through GIS approaches. Besides, GIS is capable of integrating data from various sources in order to provide information regarding land use planning. As has been stated by Royal Town Planning Institute [4], GIS can provides many benefits in urban planning such as improved mapping and analysis, faster and more intensive access, have greater effective in retrieving information and improve the quality of services. GIS software can produce clear maps with much information. The potential hazards can be easily identified by the maps that will be produced from GIS software. It has been proven by Forkuo [5] which states that the component of GIS software is hazard mapping that functions to produce community vulnerability inventory.

This study takes place in the Peninsular of Malaysia, specifically in the southern part of Kuala Krai district. It is important to determine the flood risk area in order to estimate flood occurrence in future. Details information in term of depth of flooding, probability of flooding and other flooding characteristics in grid datasets form is one of the ways that can be taken to reduce the flood risk. Therefore this study was conducted to give essential information containing strategy development and planning adaptation which can be provided by a reasonable flood risk analysis.

2. Methodology

2.1 Study Area

The study area is located in Olak Jeram area of Kuala Krai district which dominated by the Forest Reserve of Kuala Krai. It is considered as a hilly area as the study area is surrounded by many hills. The highest elevation of the study area is 440 m. Sam River is the main river within the study area. Sam River is the division of one of the main rivers in Kelantan, Lebir River. Figure 1 indicates base map of Sg. Sam, Kuala Krai, Kelantan. According to [6], the granitic rocks were distributed in the east borders (the Boundary Range granite) of the state of Kelantan. Usually it leads to the formation of skarn along contact zones. Besides, through this research, the only concern area is Kuala Krai area which comprised of Taku Schist Formation. Works by [7] has shown that the depositional environment of this formation is typically shallow marine with intermittent active submarine volcanism. For flood risk analysis, data such as DEM, satellite images and field study must be combined together in order to estimate depth of runoff. This research involves the use of ArcGIS 10.2 software for data processing in helping producing map of flood risk in Sg. Sam area.

2.2 Data Preparation

The spatial data used for the production of the flood risk map is listed in Table 1.

2.2.1 Water level

Table 2 indicates the maximum water level of Lebir River in Tualang Area. The level of water is divided into four main parts which are the normal level, caution level, warning level and danger level. Each of these levels has their own level within the river channel. For the danger level, it marked the water level as the same level with river bank. It means that the flood will likely occur when the water level is above the danger level. Therefore, the depth of flood flow from the river can be shown in Equation 2.1 Where;

Flood depth= Water level measured (above danger level) – Danger level of water. (Equation 2.1)

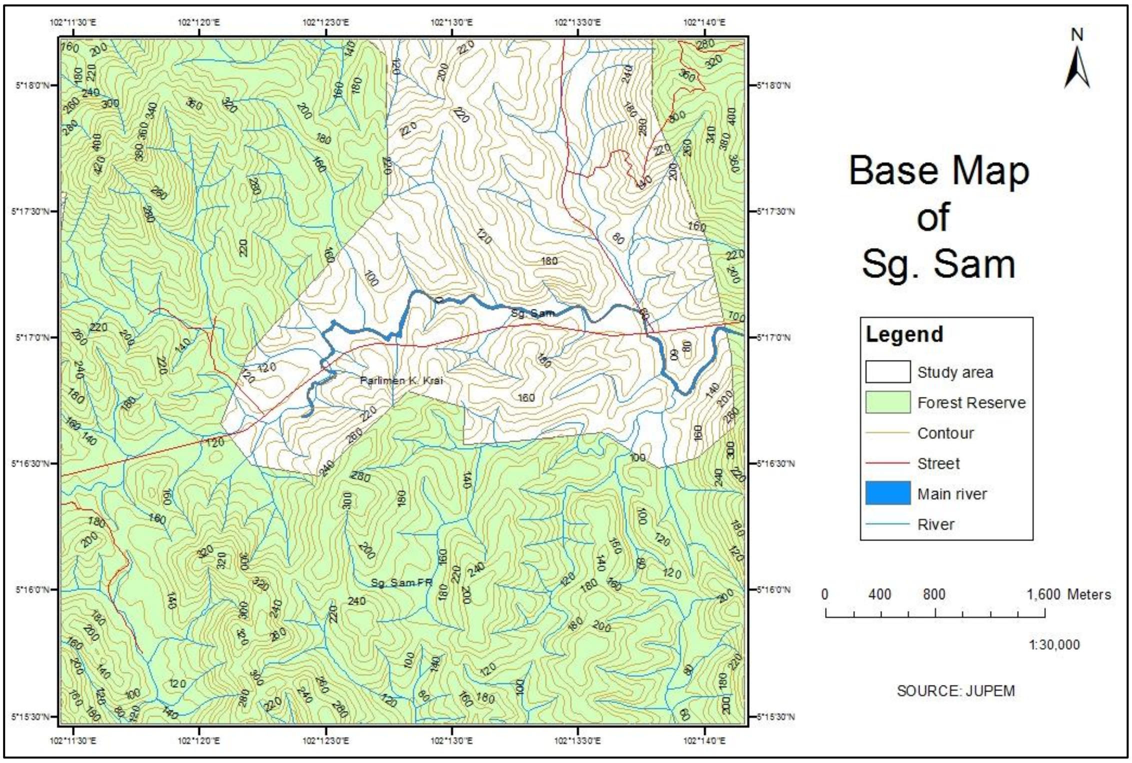

Figure 1. Base map of Sg. Sam, Kuala Krai, Kelantan

Table 1. Data preparation.

Data	Description	Source
Satellite Image	Landsat 8 OLI/TRS Acquired on 4/2/2014 & 3/7/2016	https://earthexplorer.usgs.gov/U.S. Geological Survey
Topographic Map	Scale 1:25,000	Department of Surveying and Mapping Malaysia
Digital Elevation Model (DEM)	Advance Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) with 30 meters pixel spacing	U.S. Geological Survey
Water level and hydrograph	Water depth station for Kuala Krai	Department of Drainage & Irrigation Kelantan
Rainfall Distribution	Average amount of rainfall (mm) at Kuala Krai station (year 2008 until 2015)	Department of Meteorological
ENVI software	Remote sensing image processing	IBM, Colorado, USA
ArcGIS Software	Processing, analysis and integration of spatial data.	ESRI, Redlands, USA

Table 2. Maximum water level of Lebir River in Tualang area

No	River (m)	Location (m)	Normal level (m)	Alert level (m)	Warning level (m)	Danger level (m)	Highest note	
							Date and Time	Level (M)
1	Sungai Lebir	Tualang	23.00	27.00	31.00	35.00	24-12-2014 06:00	42.17

(Source: Department of Irrigation and Drainage (DID) Kelantan)

2.2.2 Flood Depth.
Analysis of 13 days of the available data on maximum rivers levels in Kelantan was made in order to analyse and assume the level of flood risk that may occur. The flood depth of the river was analysed in detailed especially Lebir River based on the three types of risk which are low (<1m), medium (1m-5m) and high risk of flooding (>5m).Table 3 shows the value of flood depth of Lebir River which also classified into 3 risks such as low, medium and high.

Table 3. Classification of flood depth according to low, medium and high risk with date of occurrence

Flood Depth	Flood Risk		
Date (December 2014)	**Low (m)**	**Medium (m)**	**High (m)**
18	1.52		
19	1.16		
20		Alert Level	
21		Alert Level	
22		3.48	
23			6.32
24			7.17
25			5.62
26		Normal Level	

2.3 Data Collection
Data was collected by using primary and secondary sources. Primary source is source that was gained by doing flood risk mapping. This step of mapping process encourages researcher to consider a few parameters like elevation of the ground surface, land cover planning and observation on rivers system. The ground truth data of elevation value during the mapping has been collected and marked by GPS. It is one of the parameters needed to determine the flood risk area. The rivers system in study area has been observed for the flood risk area determination. Besides, land cover planning encourage researcher to determine the type of land cover during mapping process in study area. It is used for the purpose of flood analysis in term of correlation between the flood risk area and land cover changes [8]. For secondary resources, DEM is used to investigate the geomorphologic characteristics of terrain in relation to the underlying influence of geology. All elevation data and subsequent derivations like slope and aspect is calculated from the created DEM. The ASTER GDEM was acquired by the website of earth explorer of U.S. Department of the Interior U.S. Geological Survey which is shown in Figure 2. It is a high quality product with a horizontal ground resolution of 30 meters. The ASTER GDEM data is used to compare with the created DEM for the flood plain of study area. Land use data was obtained from a classified from Landsat 8 images. Field measurements were made to collect hydrologic data such as channel width, channel depth and flood levels.

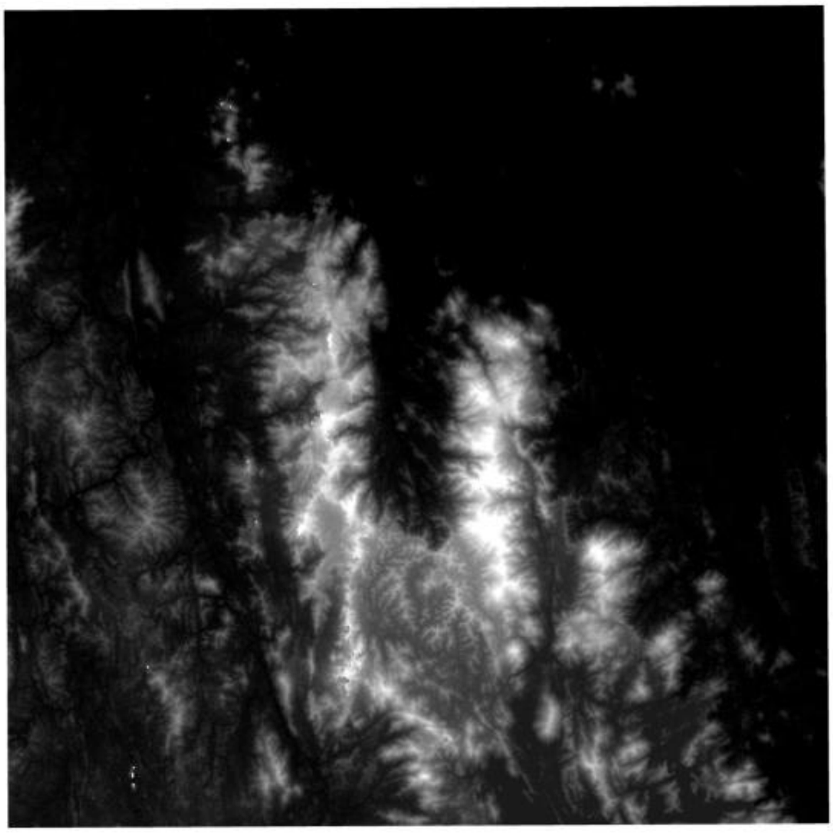

Figure 2. Aster GDEM

2.4 Data Processing

Data processing is the second step to be conducted. It involved data input, data integration and map digitizing. Data input used in this research includes elevation data, water level and land cover map. The elevation data is used for creation DEM. The topographic map (Projected coordinate system - Kertau-RSO-Malaya-Meters, prime meridian – Greenwich and scale 1:25 000) for the study area was obtained and scanned during the field work. Next, from the map, the elevation points were digitized. Data integration is a combination of sources, primary sources and secondary sources. Map digitizing involved the overlay of all data to produce flood risk area map. The input data are processed in ArcGIS software before the final product is produced. Overlay of flood risk area map and land cover classification of examined year are processed to identify the changes made before and after flooding.

2.5 Data Analysis and Interpretation

DEM was analysed in term of accuracy to determine the most accurate model for flood risk analysis. Next, the data related with flood risk area was analysed together to get the flood risk area map. The data such as maximum daily rainfall was used to identify and separate flood risk area in the study area. Besides, the water level of river near the study area is analysed to determine the flood depth. Thus, flood risk area is distinguished based on its potential to produce runoff for different elevation of ground surface and water level of the area. The flood risk area map was then used to correlate with the land cover changes. The analysis is basically in form of how much the area of classified images (after flooding) has been changed from the previous image (before flooding).

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3. Results and Discussion

3.1 Digital Elevation Model

The map presented in Figure 3(a) shows the created DEM of flood plain in study area while Figure 3(b) shows the ASTER GDEM map after undergoes pre-processing process. The high value of elevation is represented by the reddish colour while the low value of elevation is represented by the bluish colour. These colours were classified solely according to the elevations of the study area. Figure 3(a) shows the elevation ranges from the lowest elevation which value is 59.9 m to the highest elevation which is 440 meters. Figure 3(b) shows a slight difference in terms of range of elevation which is from 60 meter (lowest) to 442 meter (highest). The river marked the low lying areas where the susceptibility of flood is high. The low elevation values can be assumed to be high risk area for flooding as well as correspond to areas as generating the largest amount of runoff. Firstly, the slopes characterized the flat areas with inferior to less than 10^{o}. Other than that, the extracted aspect from DEM also helped in explaining on why that zone is more susceptible to flooding event. The value presented is -1, which indicates the flat areas are dominant in that zone. Thus, the flood will probably start to flow from the eastern part to the western part of study area. So, it can be concluded that as the elevation increases towards the westward, the susceptibility to flooding decreases.

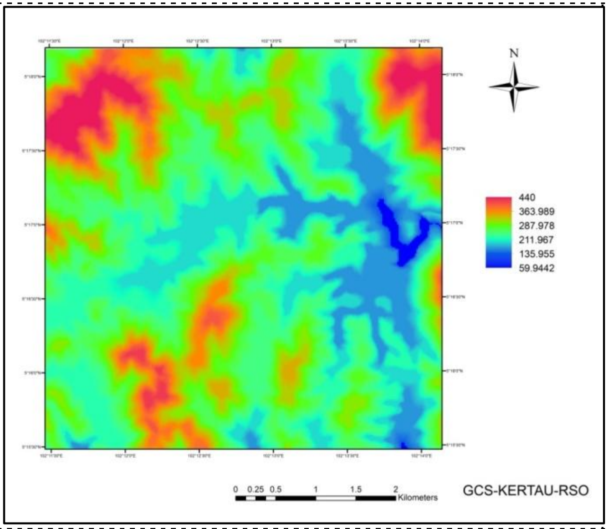

Figure 3(a). Created DEM in study area

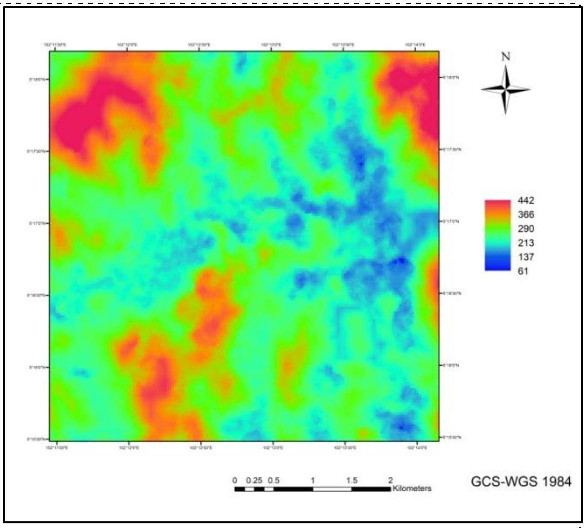

Figure 3(b). ASTER GDEM of the study area

3.2 Flood Risk Map

Figure 4 shows the study area with the risk of flooding in Sg. Sam area. The map defines 3 important levels of risk ranging from low to high. Areas with low risk cover 4% of Sg. Sam area while medium risk area and high risk area cover respectively 9% and 7.8% of Sg. Sam area. The unclassified area possessed no threat of risk due to few factors related to possibility of flood occurrence. The low risk areas are evenly distributed in study area. It is characterized by the high slope, plantation areas, low rainfall and low water level. The flood depth in this area may reach just below than I meter. The medium risk of flood area also covered the plantation areas but has a lower slope than low risk area. For the high risk area of flooding the, it covers the low and flat slope area which less than 3 meter and this area covers mostly the urban areas. Heavy rainfall also contributes in trigging flooding in high risk area.

3.4 Land Cover Classification

Figure 5(a) and 5(b) show the classification of land cover in Sg. Sam area. The area has been classified according to five different classes of areas namely bare land, build up, plantation, forest and water body. Different colours were assigned for different classes of areas. Both of the figures illustrate the land cover from Landsat 8, OLI satellite image with the first figure illustrates image on 4/2/2014 while the second figure's image is 3/7/2016. The land cover changes indicate pre-flooding and post-flooding events. Generally, the bare land area in year 2016 covered much of study area rather than area in 2014. This is because of the erosion process that took place after flooding occurred. Besides, the built up and forest area have decreased in their area from year 2014 to 2016. This suggested that, much buildings and forest areas have been affected by flood occurred in 2014. The plantation area is increased in year 2016 compared to plantation area in 2014. It is due to the replantation process that has been made after the flooding occurred.

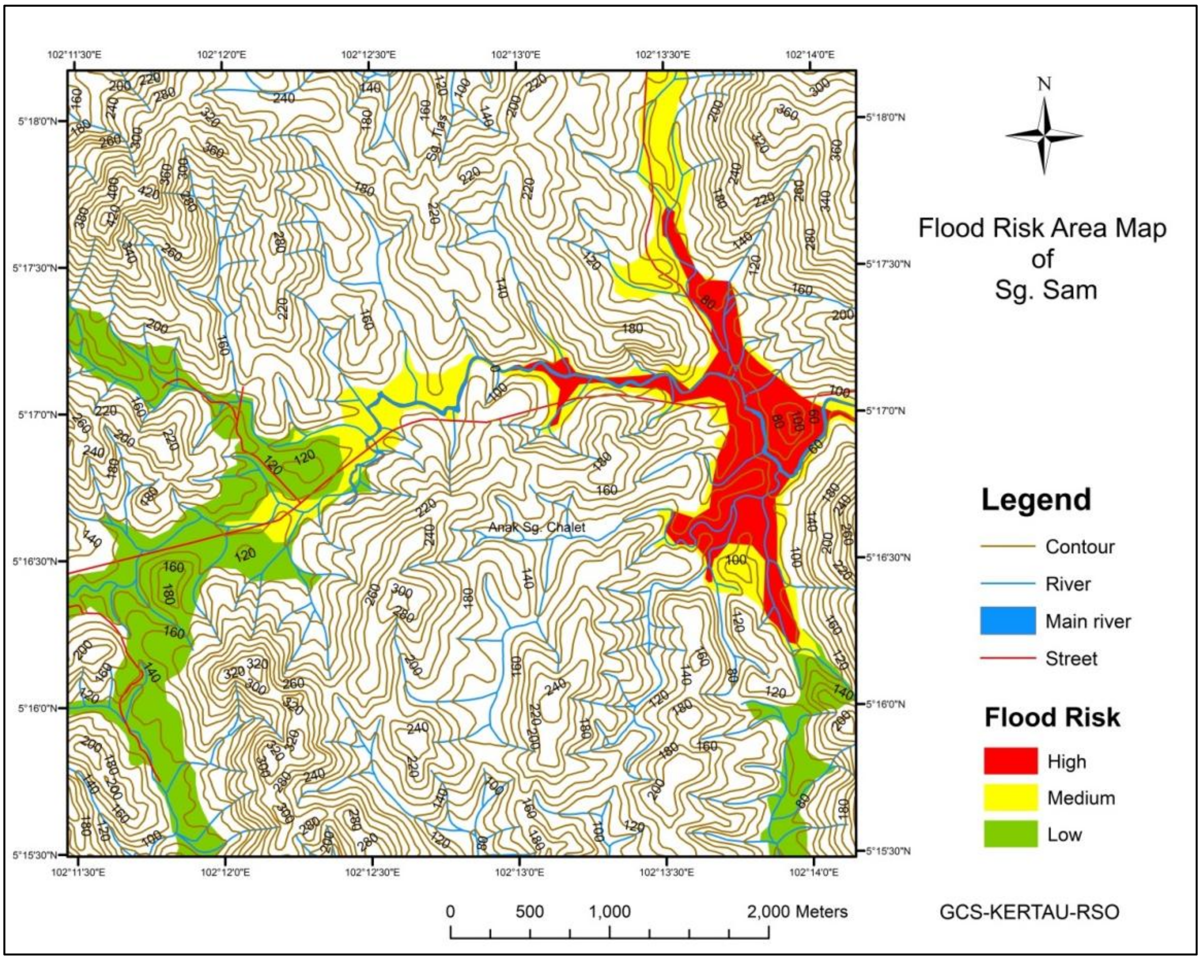

Figure 4. Flood risk map of study area

Besides, the analysis of flood risk area has been made further through the studies of land cover changes at different flood risk zone (Table 4). The changes of land cover are discovered through the comparison of land covers between two different data inputs (Landsat images) which are data of 4/2/2014 and 3/7/2016. The result showed that the significant decrease of plantation area has occurred in high risk zone due to flooding event in 2014. In medium risk zone, the significant changes occur on plantation area too. It implies that many of the planation like rubber trees and oil palm trees in study areas are decreased in amount after flooding occurred. In low risk zone, most of the land use types affected by the flood are urban areas. The urban areas include road, houses and other development structure.

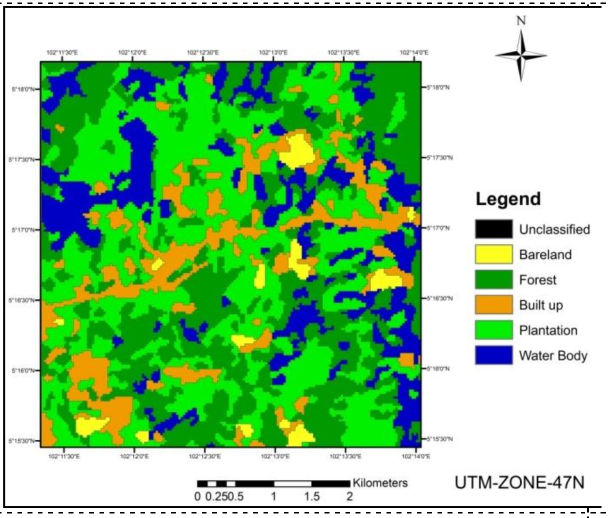

Figure 5(a). The classification of land covers in Sg. Sam area (4/2/2014)

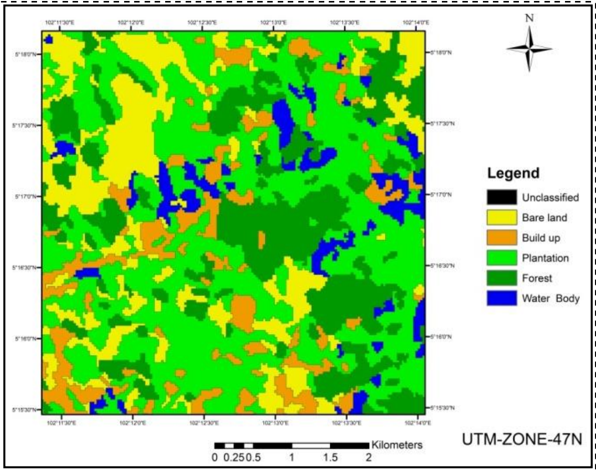

Figure 5(b). The classification of land covers in Sg. Sam area (3/7/2016)

Table 4. Differences of areas for land cover class year 2014 and 2016

Classes of Land cover	**High (km^2)**		**Medium (km^2)**		**Low (km^2)**		**Total (km^2)**	
	2014	2016	2014	2016	2014	2016	2014	2016
Bareland	0.08	0.009	0	0.1	0.1	0.5	0.2	0.6
Build up	0.5	0.2	0.1	0.4	1.4	0.5	2.0	1.1
Forest	0.2	0.1	0.2	0	0.4	0.4	0.8	0.5
Plantation	0.7	0.03	0.5	0.1	0.8	0.6	2.0	0.7
Water body	0.8	0.3	0.6	0.3	0.3	0.3	1.7	1.0
Total	2.28/	0.63	1.4	0.9	3.0	2.3	6.7	3.9

4. Conclusion

The flood risk area map of Sg Sam was generated through data processing process using ArcGIS software. It showed three particular level of flood risk depending on parameters such as amounts of rainfall, water level, flood depth and DEM. As a result, flood risk area map can be classified into three different particular levels namely low, medium and high. The recommendations regarding of this research are essential to help the studies of future research. Some suggestions are made to enhance the accuracy of work. For the flood risk analysis, relevant information related to flood starting time, flow velocity and flood extent should be provided in order to reduce the economic loss which is usually associated with flood and waterlogging.

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