Flood Risk Mapping Using Satellite Images and GIS Tools: A study on flood analysis of Thabaung, Kangyidaunt and Pathein Area, Ayeyarwady Region

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Abstract

Flood continues to be one of the most common natural disasters in Myanmar. The study area is located in Ngawun Riverine area, and it is demarcated between latitude 16º 43' N to 17º 10' N and longitude 94º 41' E to 94º 57' E. The area coverage is about 1278 square kilometers. Google Earth, Surfer 11, Global Mapper 17 and ArcGIS 10.1 were applied for various kinds of mapping and data analysis by using remote sensing data, topographic maps, census data, DEM data, and rainfall data. In 2016, the annual rainfall of Ayeyarwady Region increase more than the normal rainfall. The final flood hazard map and vulnerable map show flood vulnerable index ranging from 1 to 5 which have been classified into five major classes. The regions with very high to high flood vulnerability index have population density in the range of about 400–3372 persons per sq.km, locating along the river. The region with the moderate flood vulnerability index have population density of about 180-400 persons. Some of the village tracts in the study area have low to very low flood vulnerability index as the population density is in the range of about 0-180 persons, with most of the forest area. The high risk index indicates the high population density, high rainfall and very flat topography. Because of less population density, large forest cover area, and more distance from river channels such as Kyunhlyargyi have very low flood risk index. The areas with intermediate values have the moderate population density and dominated with agricultural land but the nearness to river channel increases the risk.

Keywords: five major classes, flood vulnerability index, population density, flood risk index

Introduction

Floods are physical global hazards with negative environmental and socio-economic impacts on local and regional scale. Floods are the most common natural disasters; their frequency, magnitude and the cost of damage are on the rise all over the world. Floods can also be caused by human interventions in the natural processes such as increase in settlement areas, population growth and economic assets over low lying plains prone to flooding, leading to changes in the natural drainage and river basin patterns, deforestation and climate change (Balabanova & Vassilev, 2010; Kwak & Kondoh, 2008).

Location and size of the study area

The study area is located in Ayeyarwady Region, south westernmost part of Myanmar. It occupies the some deltaic areas of Thabaung, Kangyidaunt and Pathein towns. It extends about 50 km in length and about 31.2 km in width, demarcating between latitude 16º 43' N to 17º 10' N and longitude 94º 41' E to 94º 57' E on UTM map sheets 1694/9, 1694/13, 1794/12, 1794/16. The total coverage is about 1278 square kilometers (Figure 1), lying in the Ngawun Riverine area.

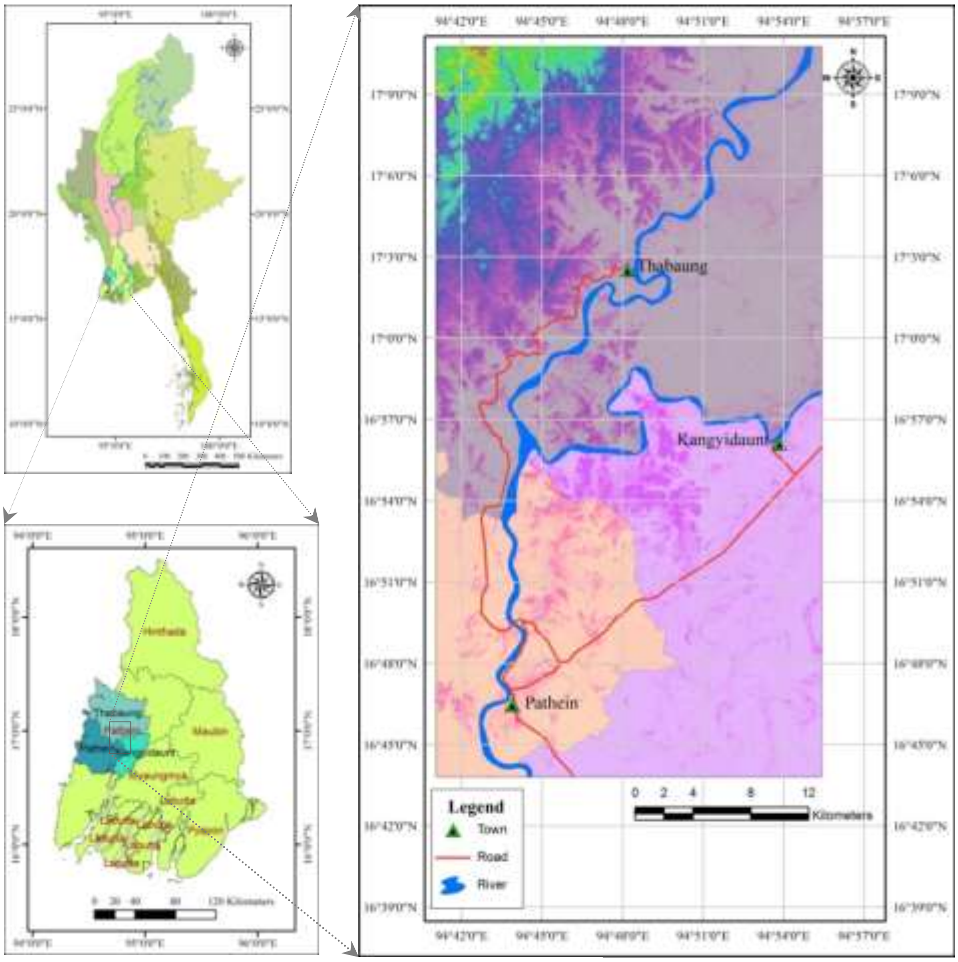

Figure (1) The location map of the study

Purposes of Research

Flood hazard mapping is a vital component for appropriate land use planning in flood prone areas. It creates easily-read, rapidly accessible charts and maps which facilitates the administrators and planners to identify areas of risk and prioritize their mitigation efforts. The geographic information system (GIS) technology is a popular tool used in risk assessment and is a form of computerized spatial data that specifies spatial position. GIS can combine geographical factors and risk assessment models to illustrate risk mapping related to different natural disasters (Peggion, Bernardini & Masera, 2008). The study area has notably suffered flood hazards especially in 2015 and 2016. The present work is carried out to understand the causative factors of flooding of the study area and to generate the flood hazard, vulnerability and flood risk maps.

Previous Works

In 2007, Aung Swe submitted a dissertation for doctoral degree on “Flood Analysis on the Western Tributaries of the Upper Ngawun River in Ayeyarwady Division” which essentially includes the morphometric analysis, surface run off condition and potential soil erosion rate of the western tributaries of the upper Ngawun River. The paper, “Vulnerability of Flood Hazard in Selected Ayeyarwady Delta Region, Myanmar” was submitted in International Journal of Science and Engineering Applications Volume 3 Issue 3, 2014 by Khin Thandar Win, Nilar Aye and Kyaw Zaya Htun. The paper mainly focused on flood vulnerable areas for different return period flood. In August 16, 2016, World Health Organization (WHO) presented the situation analysis and response of "Myanmar Floods". This report highlights the affected population, relief measures, casualties and damages in 2016 floods. In August, 2016, World Food Programme (WFP) reported the flood affected population, area and their food assistance, relief cash-based transfers and supply chain in 2016 floods.

Data and Methods

The flood risk map of study area has been generated by considering different thematic layers of the flood controlling factors. These thematic layers were prepared using remote sensing data (Landsat-VII), Topographic maps, population data, SRTM DEM data, and rainfall data. The different data sets were analyzed for generated information as geomorphic features, population density, landuse/landcover etc. The SRTM DEM was analyzed for the generation of slope map. All the data/thematic layers derived from different sources were converted to grid format which will be used in GIS analysis. Finally, all data was integrated in a GIS environment using multi-criteria decision tools for preparation of flood hazard, vulnerability and flood risk maps. Details of the data used for this study and the methods employed were described in below section.

Table (1) Lists of satellite data used for analysis

Data type			Month/Year of Acquisition	Ground Resolution/ Scale
Satellites	Sensors	Path/Row		
Landsat–7	ETM	LE07_L1TP_133048	2000, 2008, 2016	30m
Digital Elevation Map (DEM)	Advanced Spaceborne Thermal Emission and Reflection	n16_e094 & n17_e094	2011	30m
	Shuttle Rader Topography Mission (SRTM)		2009	90m
			2015	30m

Table (2) Lists of maps used for the analysis

Map	Creation Date	Detail	Data Source
UTM topographic maps (1694-9,13 & 1794-12,16)	First edition, 2004	Scale - 1:50,000 Myanmar datum 2000	Survey Department, Ministry of Forestry
Population and population density in Ayeyarwady Region (2014 Census)	July, 2016	Geographic/ WGS84	2014 Census (MIMU)
Flooded area in Kangyidaunt and Thabaung Township	August, 2015	Geographic/ WGS84 Scale - 1:70,000	RRD/ EOC/ MIMU
Village tract of Ayeyarwady Region	August, 2016	Geographic/ WGS84	MIMU
Village tract population of possible flood-affected areas	December, 2015	Geographic/ WGS84	RRD/ EOC/ MIMU

Applied Data

The major information, population distribution is largely related to the degree of accessibility and the concentration of economic activities. Most of the population is highly concentrated on the urban areas. The Latest Census data of 2016 has been taken from General Administration Department (GAD) of Pathein, Thabaung and Kangyidaunt townships and other recorded data have been obtained from literature survey. The other information, the rainfall data used for the Risk analysis is obtained from training seminar "Training on Forecast Translation, Application and EWS Audit" and "Department of Meteorology and Hydrology (Pathein)". The 2016 rainfall data and Normal rainfall data of Ayeyarwady Region were mainly applied in hydrological analysis for flood hazard mapping.

Field data were collected by using global positioning system (GPS), magnetic compass, geological hammer, and topographic maps and questionnaires surveys also made on affected person who live in flooded areas. A field visit for the collection of topographic points and ground validation was done during September 2016. For the geomorphologic mapping, various features has been mapped and validated with the ground data collection.

Methodology

The methodology mainly relies on analysis of the satellite images, SRTM 30m DEM and field survey by using GIS tools. It involved several steps such as (1) Desk study was made on literature survey and remote sensing; (2) Field data collection using GPS; (3) Processing and generation of different thematic layers according to the availability of the data; (4) Integration of all data sets, preparation of final risk map for the study area, and interpretation of the results; and (5) Finally, the validation of the results generated. The following pre-processing technique has been applied to remote sensing using Google Earth, Surfer 11, ENVI 5.0, Global Mapper 17 and ArcGIS 10.1 application.

GIS integration of data layers and generation of Flood risk map

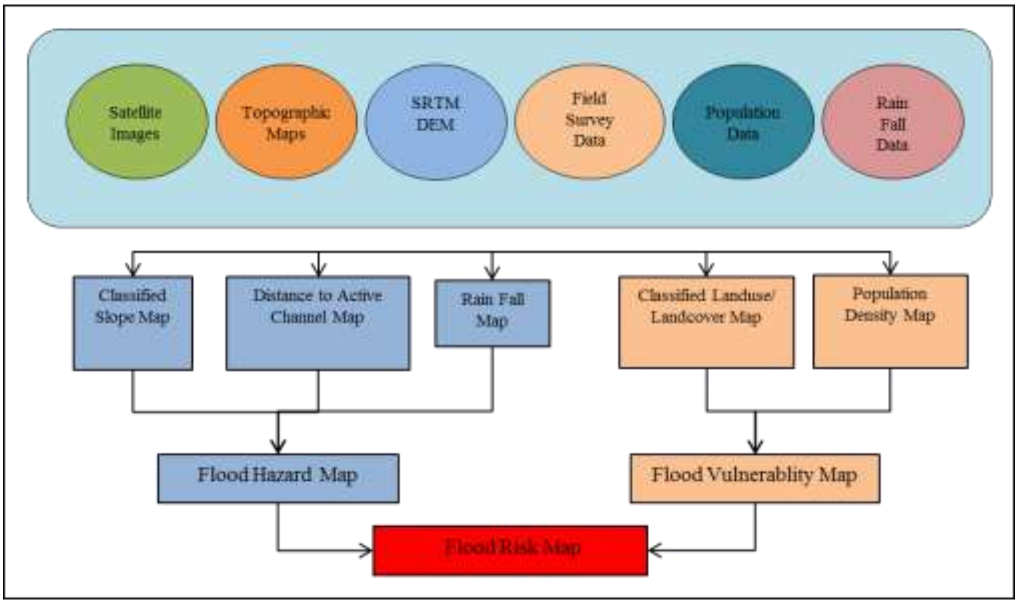

Figure (2) Flow chart of the Integration Phase (ArcGIS) for generation of flood risk map

The different satellite images that were used for the generation of the thematic layers are SRTM DEM and Landsat–7ETM. Landsat–7 imagery for the geomorphic map was done by on screen digitization of the georeferenced satellite images. The digitization of various geomorphic features based on the visual interpretation of user. Finally all the generated thematic layers that have been developed by the different sets of data types will be integrated in the GIS platform. Out of five thematic layers, three thematic layers namely slope, rainfall and distance to active river channel are used to generate flood hazard index. The remaining two thematic layers namely the landuse/landcover and the population density were used to generate flood vulnerability index. The two-flood index maps were combined by simple multiplication to form the final risk index map.

Results and Discussions

Thematic layers have been prepared through different sources of the available data sets based on the understanding of the causative factors of floods in the study area. An integration of flood 'hazard' and flood 'vulnerability' maps has been used to generate the final flood 'risk' map. The basic idea is to classify the study area in terms of flood risk based on the choice of variables considered (Table 3). Five factors have been considered namely, population density, slope, distance to the active channel, rainfall for the hazard analysis and landuse/landcover and population density of the study area for the vulnerability analysis. The hazard leads to the probability of damaging the physical environment of the given area and the vulnerability leads to the loss of the physical, social and structural damage, destroyed or loss of life.

Table (3) The parameters used for the flood risk analysis

Flood Hazard Analysis	Vulnerability Analysis
1. Rainfall	1. Population density
2. Slope	2. Landuse-landcover
3. Distance to active river channel	

Rainfall of the Ayeyarwady Region

Myanmar climate is a tropical monsoon type. The wet period stretches from May to late October. During this time, strong winds blow into Myanmar from the southwest, bringing thunderstorms with heavy rain almost every day. Averagely, Ayeyarwady Region receives about 78 to 138 inches of rainfall per a year. Due to monsoonal rains, which occur between mid-May and mid-October, the volume of the Ayeyarwady River and its tributaries varies greatly throughout the year. In 2016, although the rainfall of Ayeyarwady Region is increase than the normal rainfall, the rainyday is decreased. The increase and decrease amount of rainfall and rainyday have been described in Table (4).

Table (4) Normal Rainfall and 2016 Rainfall of the respective townships of Ayeyarwady Region

	Normal Rainfall		2016 Rainfall		Increase (+) / Decrease (-)	
Township	Rainfall inch	Rainyday	Rainfall inch	Rainyday	Rainfall inch	Rainyday
Pathein	102.09	107	125.86	108	23.77	1
Kangyidaunt	85.84	103	99.68	103	13.84	0
Thabaung	97.67	108	118.12	101	20.45	-7
Ngapudaw	91.42	110	96.72	95	5.3	-15
Kyonpyaw	74.18	98	97.67	95	23.49	-3
Yegyi	91.81	99	110.53	100	18.72	1
Kyaunggon	76.31	97	94.73	96	18.42	-1
Hinthada	78.9	98	89.2	93	10.3	-5
Zalun	82.28	103	82.94	103	0.66	0
Lemyethna	76.51	93	94.75	79	18.24	-14
Myanaung	44.66	77	83.56	65	38.9	-12
Kyangin	44.48	85	49.84	72	5.36	-13
Ingapu	65.4	90	56.72	74	-8.68	-16
Myaungmya	76.25	107	106.59	101	30.34	-6
Einme	72.3	105	94.82	101	22.52	-4
Wakema	83.92	102	107.01	99	23.09	-3
Labutta	110.77	109	142.4	104	31.63	-5
Mawlamyinegyun	75.59	101	106.44	87	30.85	-14
Maubin	84.17	106	82.42	100	-1.75	-6
Pantanaw	69.21	104	74.59	91	5.38	-13
Nyaungdon	73.37	105	82.72	92	9.35	-13
Danubyu	70.66	103	87.58	82	16.92	-21
Pyapon	92.1	109	116.93	103	24.83	-6
Bogale	90.63	105	138.35	100	47.72	-5
Kyaiklat	101.1	100	127.94	108	26.84	8
Dedaye	99.91	104	101.57	78	1.66	-26

Source: Department of Meteorology and Hydrology (Pathein)

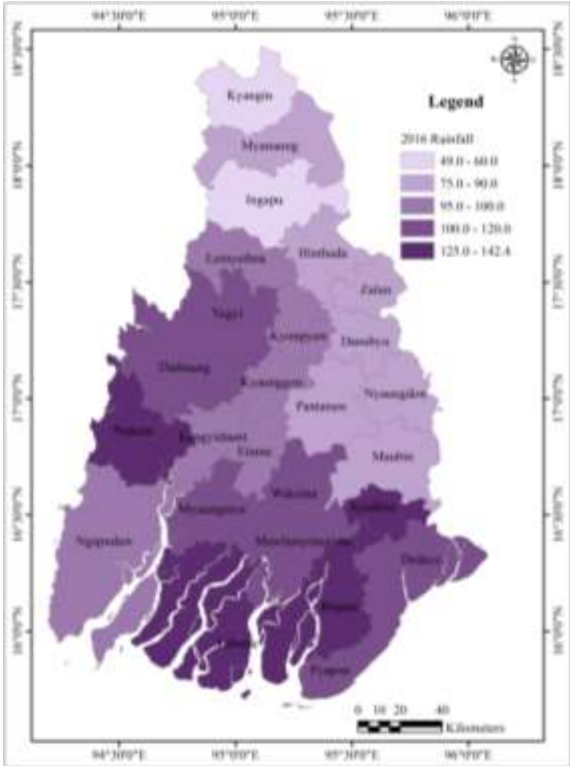

Figure (3) Rainfall distribution map of Ayeyarwady Region (based on Table 4); Source: Department of Meteorology and Hydrology (Pathein)

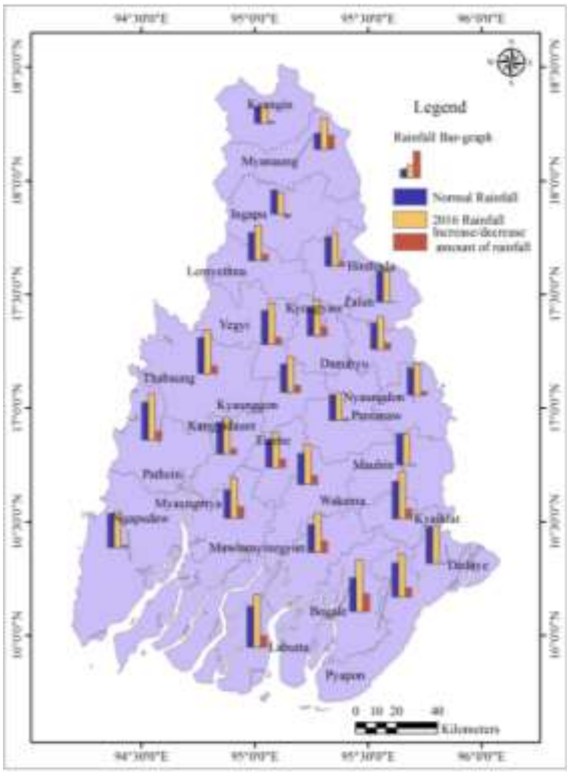

Figure (4) Rainfall distribution bar graph map of Ayeyarwady Region (based on Table 4); Source: Department of Meteorology and Hydrology (Pathein)

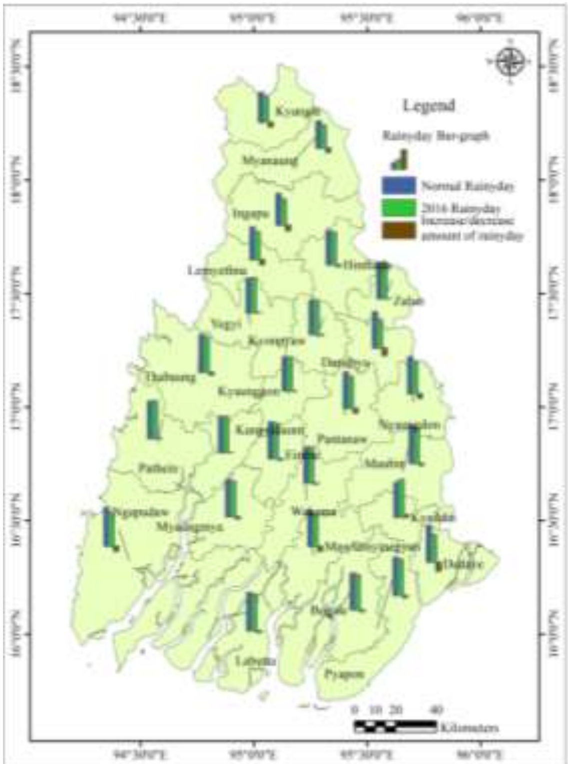

Figure (5) Rainyday distribution bar graph map of Ayeyarwady Region (based on Table 4); Source: Department of Meteorology and Hydrology (Pathein)

Classified Rainfall Map

Study area is located in Ayeyarwady delta and possesses high rainfall. According to IDW interpolation, the annual rainfall of study area is about 88 to 118 inches. The rainfall of the western part of the study area is higher than the eastern part. Especially, Thabaung area gets more rainfall than the other part of the study area.

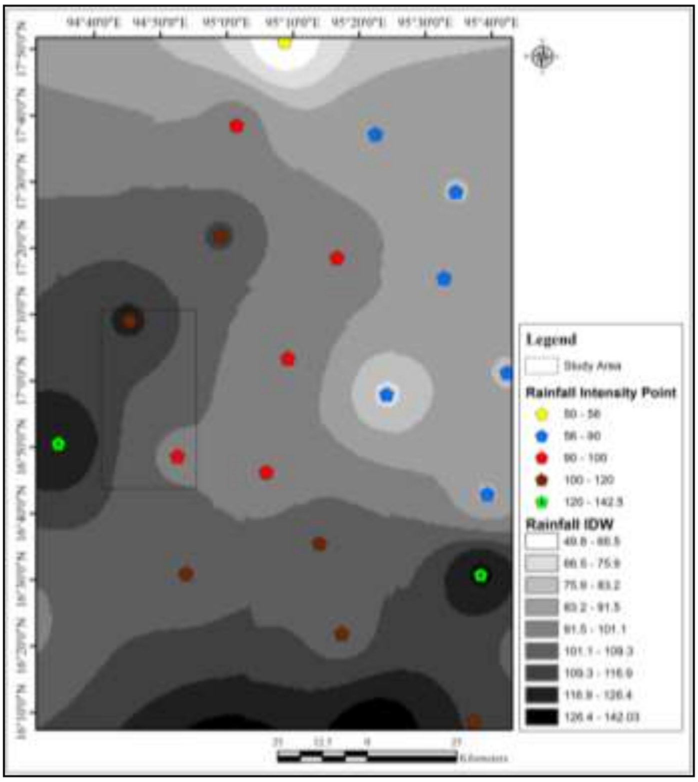

Figure (6) Rainfall distribution map of Ayeyarwady Region (based on Table (4) by IDW interpolation) Source: Department of Meteorology and Hydrology (Pathein)

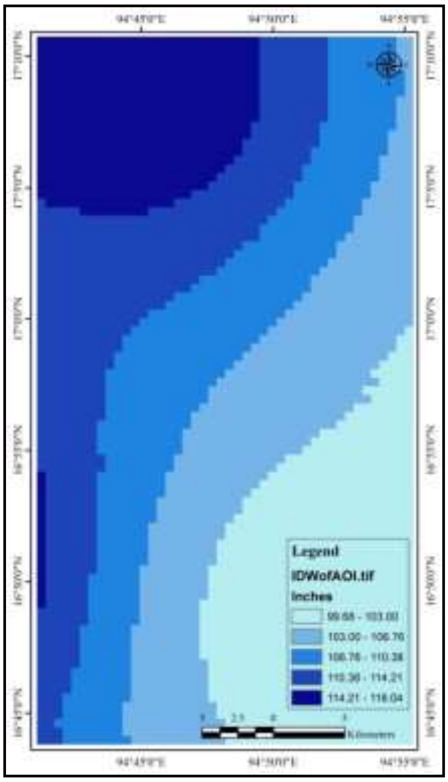

Figure (7) Classified rainfall distribution map of study area (based on Table (4) by IDW interpolation) Source: Department of Meteorology and Hydrology (Pathein)

Classified Slope Map and Distance to Active River Channel Map

The length and the steepness of the topographic slope affect the flow and inundation of the particular area. For example, low and flat topography decreases the runoff, causing high infiltration within the area thereby resulting in water logging condition. Also, the low-lying area with low slope angle will be inundated first as compared to the high slope area during flooding. That area with steep slope show high peak discharge as compared to the low-lying area and causes the depletion of the storage in the upstream areas.

The study area is a flat topography and the slope variation is very less (0.05°–26.55°) as derived from the SRTM DEM slope map. This will cause the slowing down of the river channel flow and the sedimentation will be high along the river course which follows the trend of the slope. Low slope angle indicates the areas with the flat topography will get inundated easily as compared to the moderate slope and high slope areas and hence given higher weightage. Higher slope will lead to high runoff and hence the effect due to flood will be less. The classified slope map has been shown in Figure (8).

The distance to active river channel will be important over the geomorphology as the hazard to the flooding will be based on or to be decided on the distance that is covered by the river during flooding. Hence the distance to active channel in hazard index has to be given a high importance. The weightage of level 3 sub-factors has been decided accordingly, higher is the distance from the main channel lower the risk and lesser is the distance could be higher in risk.

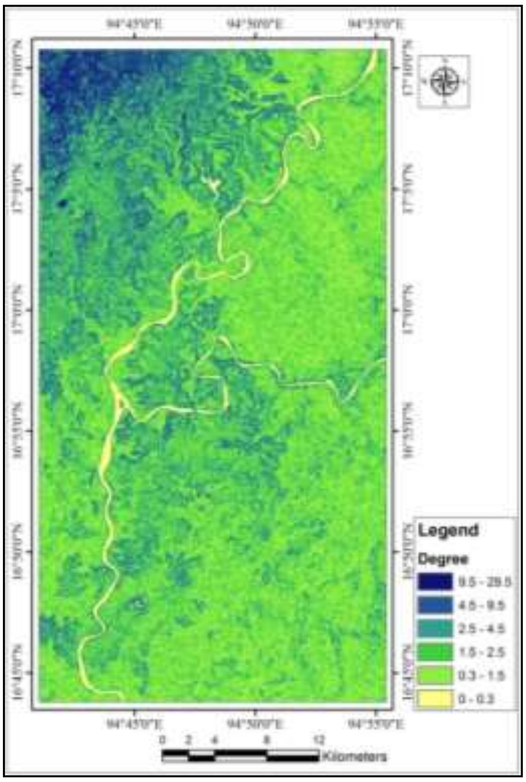

Figure (8) Classified slope map of the study area; Source: 30m SRTM

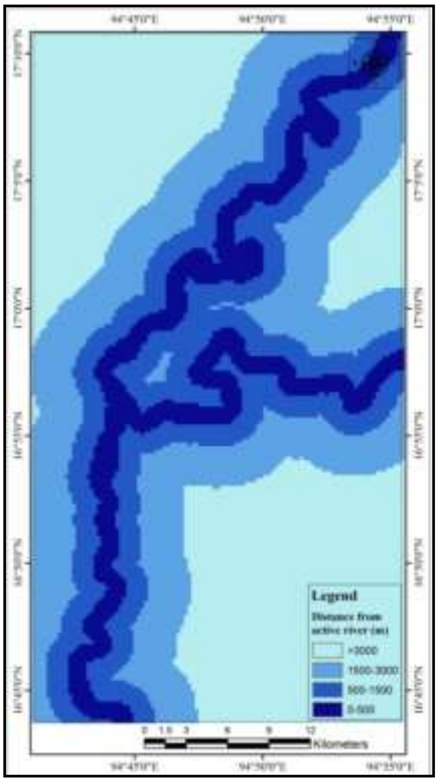

Figure (9) Distance to active river channel map of the study area

Population Density Map

Population density and distribution influences physical processes and economic conditions. The settlements of town and villages are situated mainly on the eastern and western banks of the Ayeyarwady River and its tributary Ngawun River. This study area is mostly occupied by mixed forest, agricultural land and wetland (it includes mixed thin soil, sand and rock and sand dunes). Seasonal crops plantations are found in floodplain area of Ayeyarwady River basin in summer season. The socio-economic factors and physical factors may contribute to soil erosion, sedimentation and flooding in Lower Ayeyarwady basin including study area.

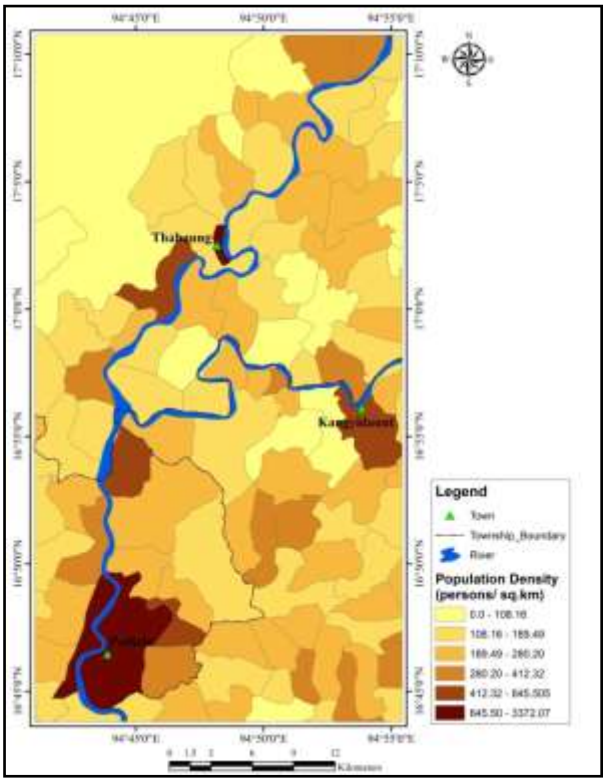

Figure (10) Population Density Map of the Study Area (2016); Source: General Administration Department, Pathein Township

Landuse/Landcover Classification

Supervised Classification was carried out on Google Earth Engine Explorer for Landsat-7 ETM image for the year 2000, 2008 and 2016. The available landuse/landcover maps include six different categories namely: mixed broadleaved evergreen forest, deciduous and shrubland forest, crop land, water, and urban and settlement (Figure 12, 13 & 14). The landcover classes represent feature on the land surface while landuse represents the activities within which the landcover is being used. This is the classification scheme of selecting the representative areas with the help of the spectral characteristic of the feature in the image. The accurate and complete classes to be defined in the supervised classification is critical in case of coarse resolution image, because not all data fit into a particular class because of fuzzy or mixed areas within the image as that of settlement and sparse forest areas in case my study area. The error matrix of the image classification was computed to determine the accuracy based on 95 random sample points. The overall accuracy was 83.6 %. Classification results are good for the major classes but there is confusion between settlement areas and moist areas in this context. Landcover class area of the whole study area for the year 2000, 2008 and 2016 are shown in Table (5). According to this table, land cover class area changed within sixteen years.

Table (5) Landcover classes area extracted from Landsat 7 ETM 2000, 2008, 2016 satellite imagery of the study area

Landcover Types	Landcover Class Area (Km^2) (2000)	Landcover Class Area (Km^2) (2008)	Landcover Class Area (Km^2) (2016)
Mixed broadleaved evergreen forest	347.497521	279.602582	213.011744
Deciduous and shrubland forest	248.93079	295.815256	303.369719
Cropland	478.5422	492.959743	503.501962
Bareland	130.225685	81.387179	92.389396
Water	39.797601	39.226594	39.973468
Urban and settlement	28.230521	84.230347	120.975408
Total	1273.224318	1273.221701	1273.221697

Source: Landsat 7 ETM 2000, 2008, 2016 satellite imagery

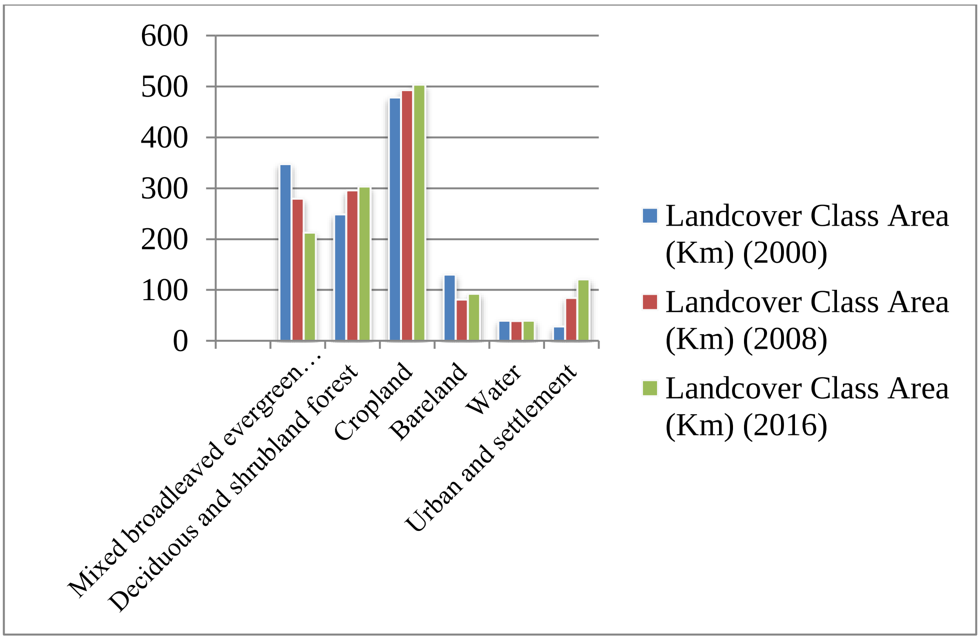

Figure (11) Landcover classes' area extracted from Landsat 7 ETM (2000, 2008, and 2016) satellite imagery of the study area

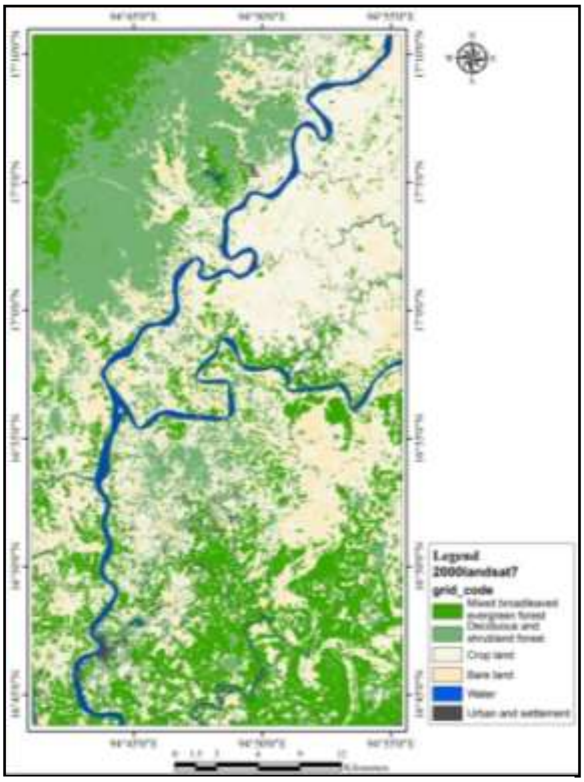

Figure (12) Landuse/Landcover Map of the Study Area (2000) Landsat-7 ETM; Source: Google Earth Engine (Landsat-7 ETM (2000) satellite imagery)

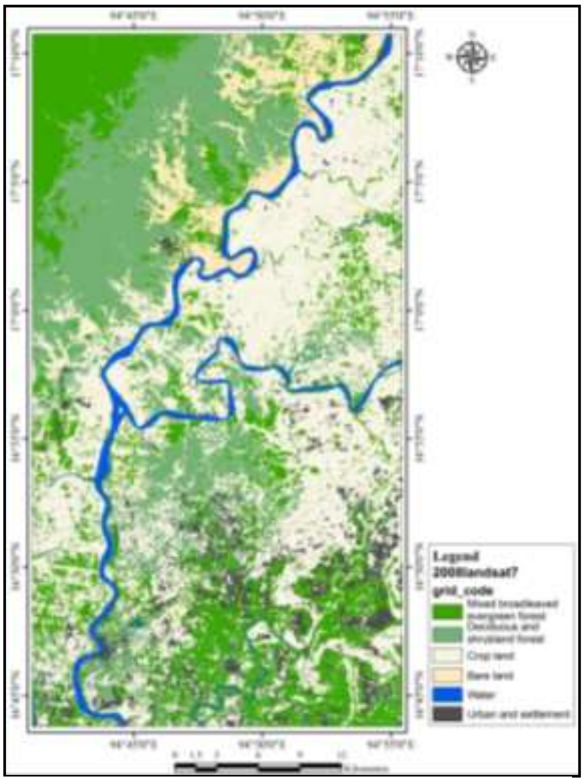

Figure (13) Landuse/Landcover Map of the Study Area (2008) Landsat-7 ETM; Source: Google Earth Engine (Landsat-7 ETM (2008) satellite imagery)

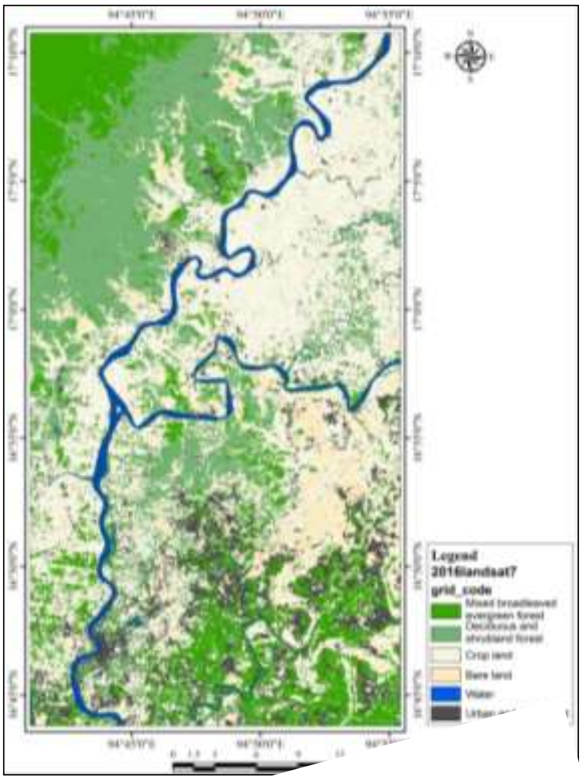

Figure (13) Landuse/Landcover Map of the Study Area (2016) Landsat-7 ETM; Source: Google Earth Engine (Landsat-7 ETM (2016) satellite imagery)

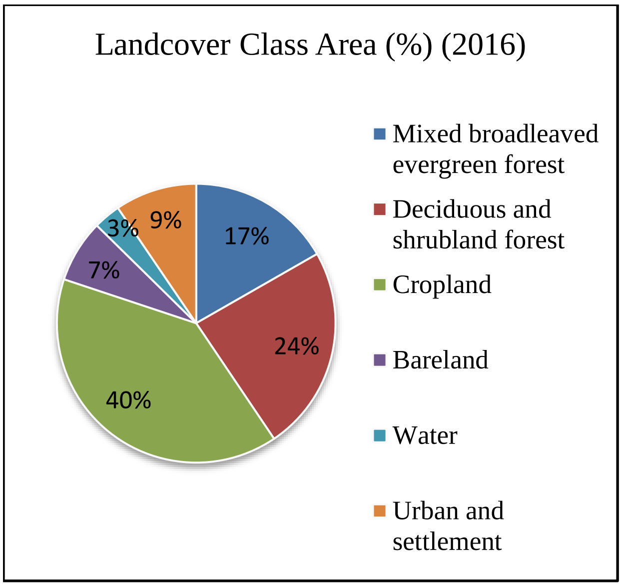

Figure (14) Pie chart of landcover class area based on (2016) Landsat-7 ETM satellite imagery; Source: Google Earth Engine (Landsat-7 ETM (2016) satellite imagery)

Generation of Flood Hazard Map

The final flood hazard map shows a continuous value ranging from 1-5 (Figure 15). The map has been classified into five major classes namely, very high, high, moderate, low, and very low (Figure 16). The map shows the area with high rainfall and low degree of slope has very high to high Flood Hazard Index (FHI). Some village tracts in Thabaung Township such as Thaminkon, Deikone, Magyikone, Hngetpyawtaw, Thitpokekone, Kyin Pauk, Thayettaw, Shingyipyauk, Magyikone, Gonhnyintan, Khattiya and Sison village tracts have very high to high Flood Hazard Index (FHI). Moreover, Ywaykone, Yway, Laysu, Kwinyar (east) and Matawtkone village tracts of Kangyidaunt Township; and Linwingyi, Thitpokekone, Ywarthit and Aungtat village tracts of Pathein Township correspond to the area of very high to high Flood Hazard Index (FHI).

Some of village tracts with moderate hazard index range include Kwinchauk, Talokekone, Taunggalay and Kwinkauk in Thabaung Township, Nanwingayet, Kularkwin and Myochaung in Kangyidaunt Township, and Shaw Pyar and Kwinpauk in Pathein Township, respectively. The village tracts which are located in hilly region yields low to very low FHI show less hazard as they are at safe distance from the active channel, the slope also helps to flow the river toward the trend of the movement.

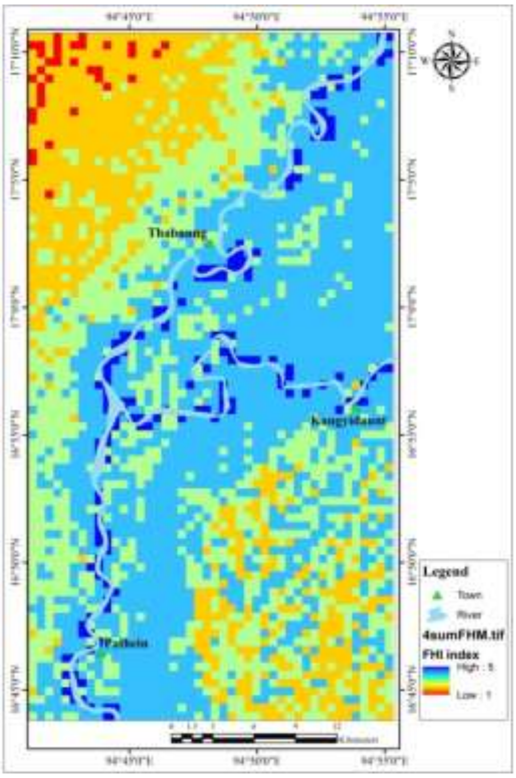

Figure (15) Flood hazard map

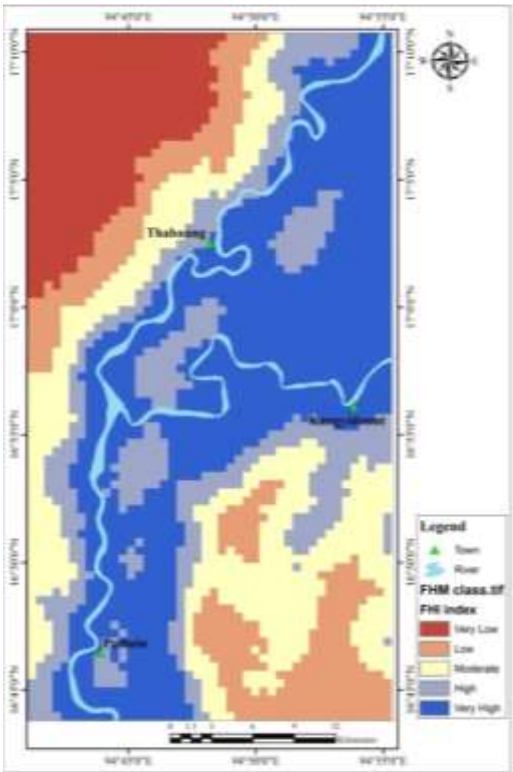

Figure (16) Classified flood hazard map of the study area

Generation of Flood Vulnerability Map

Although maps of individual components of vulnerability can be useful, multidimensional components can be integrated into a single measure and it will be easy to assess the vulnerability for the study area. The final vulnerable map has been represented with graduated scale of color, indicating the flood vulnerable index 0-60 (Figure 17). The final vulnerability map (Figure 18) has been classified on into five different classes (very high, high, moderate, low, and very low).

The regions with very high to high FVI has population density in the range of about 400–3372 persons per sq.km, they are located along the river. The region that includes the moderate FVI range have population density of about 180-400 persons. Some of the village tracts in the study area have low to very low FVI index as the population density is in range of about 0-180 persons with most of the area associated with forest area.

Table (6) FVI index and associated village tracts and towns of the study area

Flood vulnerability index	Associated village tracts and towns		
	Thabaung Township	Kangyidaunt Township	Pathein Township
High to very high	Thabaung Town, Deikone, Gonhnyintan, Hpayarkone, Kwinpauk, Thayettaw, Khattiya, Thaminkone, Sinlan, Hnagetpyawtaw, Zeephyukwin, Meethwaytaik, Thitpokekone, Sison, Shingyipyauk, Shwenyaungpin	Kangyidaunt Town, Kwin Yar (east), Yway Kone, Yway, Matautkone, Takongyi	Pathein City, Pyinkadoekone, Thitpokekone, Linwingyi, Ywarthit,Shwemyintin
Moderate to high	Shankwin, Lahargamon, Magyikone, Lintakya, Okeshit, Nwenichaung, Dakanyaungkone, Kyutpyin, Kintat, Eisoechaung, Hlaygyitet, Saungbon, Thaephyu, Aungtat	Kyungyi, Makukyun, Shawkone, Letpan, Chaungsauk,	Hpayarchaung, Kyaukchaung gyi, Minkone, Htankantlant, Kyaukpankone, Kwinpaukgyi
Moderate to low	Talokekone, Taungkwin, Taungkalay, Kwinkauk, Shanmamyaung, Kintat	Kyungyi, Wardu, Yaechokone, Yaetwinkone, Kyuntawkone, Paukkone, Kyunhlyarshey, Pitaukpin, Laysu, Kularkwin, Shanywar, Thaunggyi, Myinkaseik, Ahhtettakhuntaing, Kyonpadoke	Shawpyar, Kanni, Zinpyunkone, Paukkone
Low to very low	Kyunhlyargyi, Pyinmahtone, Kwinchauk	Nanwingayet, Kweetaw, Nyaungwaing, Thaephyu	Ahpinhnitse, Koesu, Kwinpaukgyi, Kyaungpankone

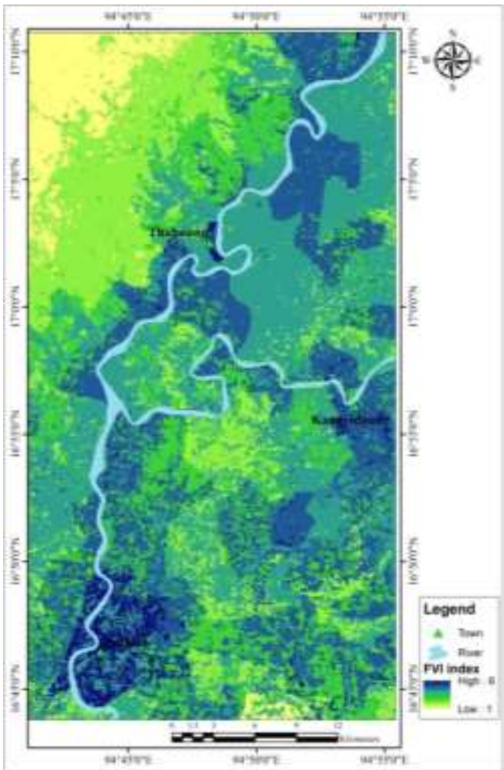

Figure (17) Flood vulnerability map

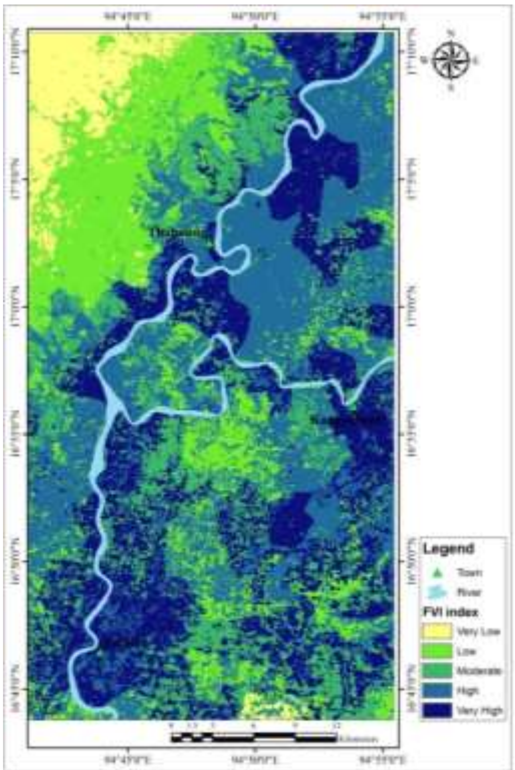

Figure (18) Classified flood vulnerability map of the study area

Generation of flood risk map

Flood hazard map and the vulnerability map were integrated to generate the final risk map of the study area in the ArcGIS overlay tool. The final Flood risk map is showing the FRI range from 1 to 5 (Figure 19). For the classification of the Flood Risk Index (FRI), a range to define the risk has been used to classify risk map into five major classes which are shown in the table below.

Table (7) Flood Risk Index with their value range

Range	Flood risk Index(FRI)
1	Very Low Risk
2	Low Risk
3	Moderate Risk
4	High Risk
5	Very High Risk

The high risk index indicates the high population density, high rainfall in the area and the area has very flat topography. Because of less population density, dense forest and more distance from river channels such as Kyunhlyargyi have low FRI. The areas with intermediate values have the moderate population density and dominated with agricultural land but the nearness to river channel increases the risk.

Table (8) FRI index and associated village tracts and towns of the study area

Flood risk index	Associated village tracts and towns		
	Thabaung Township	Kangyidaunt Township	Pathein Township
High to very high	Thabaung Town, Deikone, Hpayarkone, Kwinpauk, Thayettaw, Khattiya, Thaminkone, Hnagetpyawtaw, Zeephyukwin, Meethwaytaik, Thitpokekone, Sison, Shingyipyauk, Shwenyaungpin, Ngawunkyoetkone, Thinganpinseik, Zeepinkwin, Magyikone, Lintarkya	Kangyidaunt Town, Kwin Yar (east), Yway Kone, Yway, Matautkone, Laysu, Kyunhlyarshey, Khonzinkone, Pitaukpin, Chaungzauk, Kyungyi	Pathein City, Thitpokekone, Ywarthit, Shwemyintin
Moderate to high	Shankwin, Lahargamon, Okeshit, Nwenichaung, Dakanyaungkone, Kintat, Eisoechaung, Hlaygyitet, Saungbon, Thaephyu, Aungtat, Gonhnyintan, Sinlan,Kanyinpin, Lahargamon, Htanzinhlakyoetkone, Mezalikwinpauk, Shwetaungkyun, Ngawundauntgyi, Talokekone, Kyutpyin	Makukyun, Shawkone, Letpan, Wardu, Yaetwinkone, Kyuntawkone, Paukkone, Kularkwin, Thaunggyi, Myinkaseik, , Kyonpadoke, Nanwingayet, Kweetaw, Nyaungwaing, Ahpinhnitse, Myatlaychaung, Kyaiklat, Ohnpinseik, Takonegyi, Michaungtayar	Hpayarchaung, Kyaukchaung gyi, Minkone, Linwingyi, Pyinkadoekone, Kyaukpankone, Kwinpaukgyi, Kanni, Zinpyunkone,
Moderate to low	Taungkwin, Taungkalay, Kwinkauk, Shanmamyaung, Kintat, Pyinmahtone, Kwinchauk, Shwezanoe, Kyunkone, Theaphyu	Yaechokone, Shanywar, Ahhtettakhuntaing, Theahpyu	Shawpyar, Htankantlant, Paukkone, Ahpinhnitse, Koesu, Kyaungpankone Yaemanaypin
Low to very low	Kyunhlyargyi		

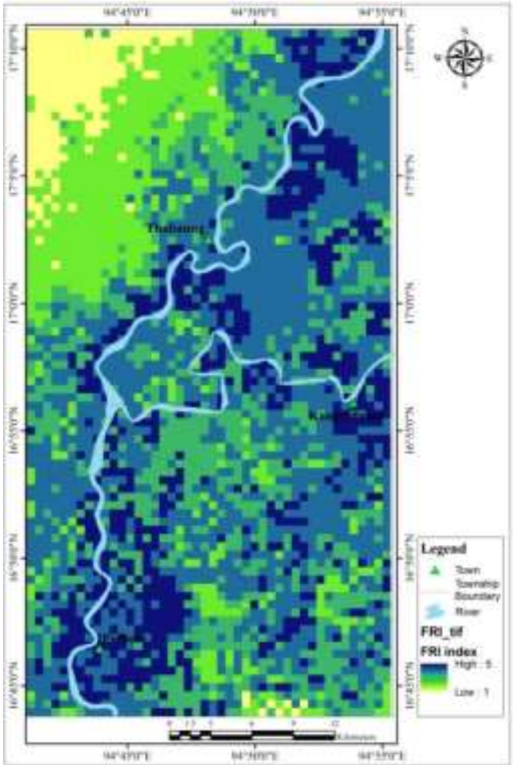

Figure (19) Flood risk map

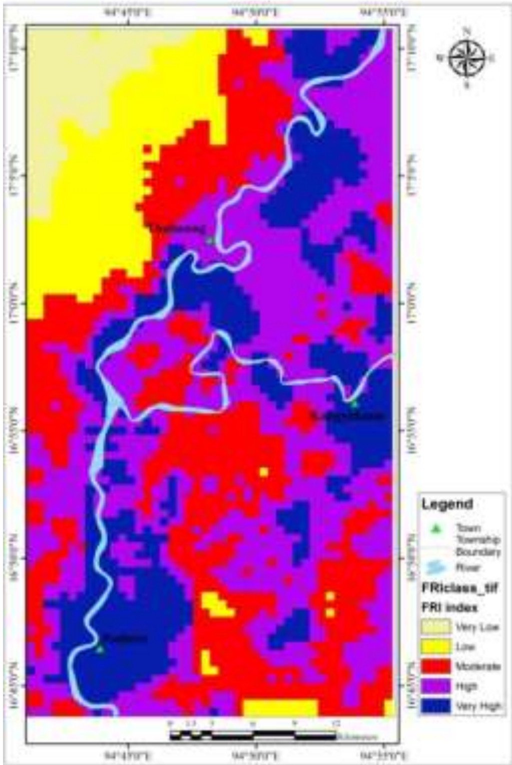

Figure (20) Classified flood risk map of the study area

Conclusion

For the study of flood risk analysis have been analyzed with the total area of 1278 sq.km. The final risk map was generated with the compilation of both hazard and vulnerability maps. The final risk map is represented with different flood risk index range. The risk map depicts the environment form, the concern and the vulnerability of the population in the area that is prone to the hazard. Therefore, the risk map takes into account the population, the areas of human activities like urban and settlements and the cultivated areas. The final flood risk map is obtained by the integration of the different thematic layers in GIS. The risk map generated is not just on the basis of inundation data but it is the result of integration of several parameters which consider distance to active river channels, slope, and rainfall. It is not simply a hydrological approach but an integrated approach in GIS environment and at the same time vulnerability map depicts all the possible consequences of the floods on the population and society.

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