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Research Paper

Identification of flood-prone areas by integrated remote sensing model

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ABSTRACT

Flood is one of the main natural hazards that normally occurs every year in Malaysia. Flood causes inconveniences to human as well as life, property and financial losses. Floods cause a range of adverse impacts, including human injuries and fatalities, damages to crop, property, and public infrastructure. In this study, the identification of flood prone area has been done by integrated remote sensing images with the Soil Conservation System-Curve Number (SCS-CN). Johor Bahru city centre and Nusajaya of Iskandar Malaysia were selected as a study area since they are involved with the rapid development. A Landsat-5 image has been used in development of elevation model while the hydrological model was utilized to estimate the peak surface runoff. Based on the result, the flood prone areas for Skudai River and the Plentong River have been identified. The rapid changes in landuse has significantly has caused these area classified as high risk of flood areas. The development of this hazard map could be a used as a guideline in planning any development in this areas.

1. Introduction

Malaysia is situated in the equatorial region, which experiences seasonal climate, i.e. with significant dry and wet seasons. During wet season, Malaysia receives high amount of rainfall which could turn to be massive disaster if the amount of water is not controlled and managed efficiently (Chia and C.W., 2002; Alaghmand and S., 2009).

Malaysia has had experienced multiple occurrences of floods and the most devastated flood event occurred between December 18, 2006 and January 13, 2007. During that period, extremely high amount of rainfall has been identified as a major contributor to the flood occurrence. This high amount of rainfall is due to Typhoon Utor which had hit the Philippines and Vietnam days earlier. Even Singapore and certain parts of Indonesia were flooded during the catastrophic event.

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The flood had caused more than 110 fatalities and RM 1.5 billion losses, collectively (Austin and Baharuddin, 2012; OFDA, 2012; Badrul Hisham et al., 2009).

Thus, the goal of this study is to simulate the flood event using satellite imagery and hydrological model to identify the flood area. Simulation results could serve as important information for mitigation purposes to reduce the damages due to flood occurrences.

2. Methodology

This study was conducted for Iskandar flagship zones. The focal development areas are Johor Bahru city centre and Nusajaya Malaysia (Fig. 1).

Iskandar located south of Johor, has a land area of 2,217 km^2. Johor Bharu city covers an area of 185 km^2, while Nusajaya has an area of 97.12 km^2.

Three main types of data collected for the study include satellite images, ancillary data including land-use map, digital elevations (DEM) and meteorological data.

In this study, Landsat 5 images are used. The image is used to generate land use map of the study area. The DEM is obtained from the ASTER database developed by NASA. The DEM is produced in a 30-m resolution. ASTER is an imaging instrument built by METI and operates on TERA platform which currently has 14 spectral bands. This includes 3 visible bands, 1 VNIR, 6 SWIR bands and 5 thermal infrared. Data such as the land use and soil map are used to determine the type of soil and for accuracy assessment.

2.1 Vectorization

In this study, the catchment area is determined automatically using Arc Hydro toolbox in the ArcGIS 10.0 software. Arc Hydro is a model developed for hydrological analysis by extracting variables from DEM. Figure 2 shows the process involved in delineating watershed from DEM. Figure 3 shows the watershed map of the study area.

2.2 Classification of land use and land cover for CN determination

The potential maximum retention/site storage S (in) is calculated based on the curve number CN, the soil type. Eq. 1 is used to determine the site storage runoff.

$$S = \frac{1000}{CN} - 10 \qquad [1]$$

The CN values was derived and estimated based on

Fig. 1. Johor Bahru city centre is marked by A and Nusajaya is marked by B.

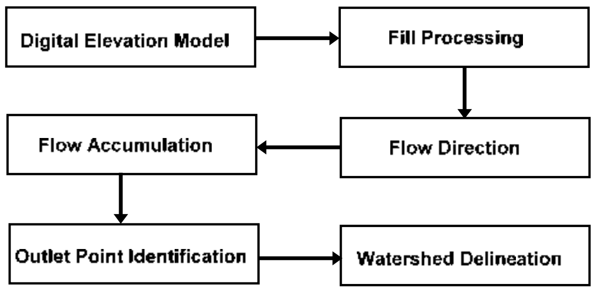

Fig. 2. Watershed delineation process.

landuse and types of soil. Table 1 shows the curve number values for several type of land use. For the purpose of identifying flood-prone area, SCS-CN model assumes bankfull discharge and uses the slope as accounted parameters.

2.3 Runoff Generation Based on SCS-CN Model

The SCS-CN model developed by the United States Department of Agriculture (USDA) has been used to determine the peak discharge. The peak discharge describes the capability of a watershed in storing water. Changes in land use will affect the holding capacity of water where increase in permeable area could lead to higher discharge (Seeni Mohd and Mansor, 2000; Mettel et al., 1994). This model focuses on the type of land use and land cover within a watershed, making it suitable for areal study involving flood. The SCS-CN model is very suitable for the study which focuses on area that experiences rapid development since it considers detailed classification of the urban soil types.

Based on the site storage S, direct runoff Q is given as:

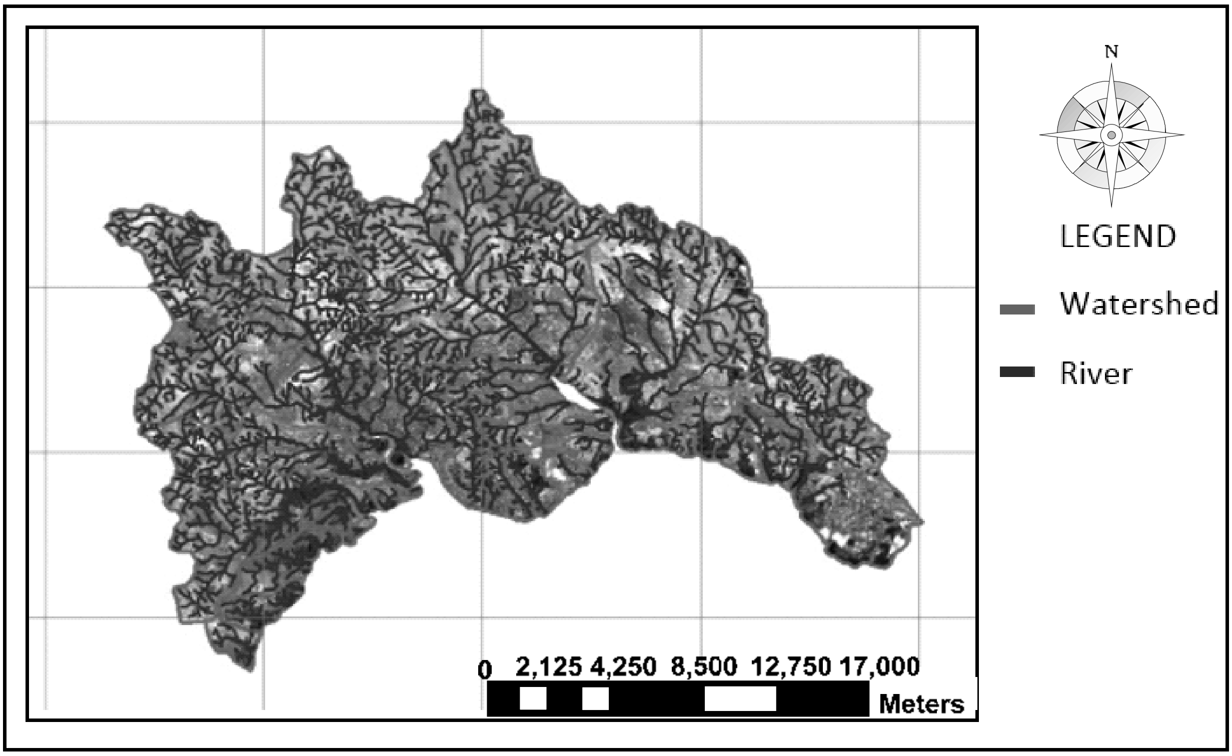

Fig. 3. Watershed map of Johor Bahru city centre and Nusajaya using satellite image.

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \quad [2]$$

where, Q = direct runoff (in),
P = rainfall depth (in),
I_a = initial abstractions (in), and
S = site storage (in).

The initial abstraction I_a are all the losses before runoff begins. The initial abstraction used in the equation refers to the USDA application in their model is given as

$$I_a = 0.2S \quad [3]$$

2.4 Calculation of Peak Discharge

Peak discharge is the maximum volumetric flow rate passing a particular location during a storm event. In this study, the graphical method of SCS-CN model is used to calculate the peak discharge of the study area. Peak discharge is given as

$$Q_p = Q_e A_m Q F_p \quad [4]$$

where, Q_p = peak discharge (cfs),
Q_e = unit peak discharge,
A_m = drainage area,
Q = runoff from Eq. (2), and
F_p = pond/swamp adjustment factor.

3. Results and discussions

Based on the analyses, the slope and elevation maps were derived from DEM and ASTER. The peak discharge is determined as well. Figure 4 shows the runoff map which had incorporated the rainfall data that were collected by the Malaysia Meteorological Department during the flood event between 2006 and 2007.

It clearly shows that the value of runoff is between 0.22 in and 3.44 in. The catchment area of Melayu River shows the lowest runoff value 0.227 in. It has been identified that the low value of runoff is due to the land use type that is dominated by oil palm plantation and it is adjacent to wetlands. Different types of land cover produce different level of infiltration and runoff (Adib et al., 2011; Razi et al., 2010). High density of vegetation slows down velocity of flow and increases infiltration capacity. Highest runoff ranges between 2.9 in and 3.8 in. The high values have been correlated with land use types since most are covered with high density of urbanization and development. This includes Danga Bay and Stulang areas, which was categorized as highly populated and

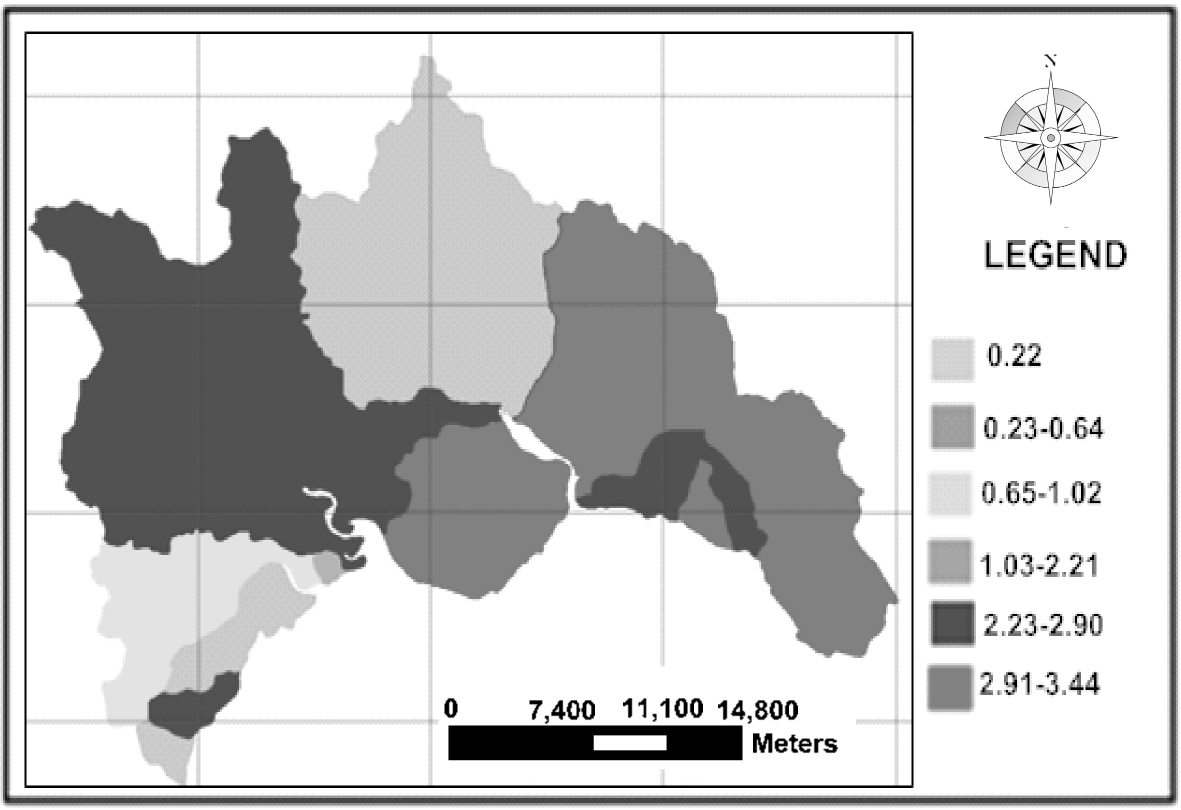

Fig. 4. Runoff map of Johor Bahru city centre and Nusajaya.

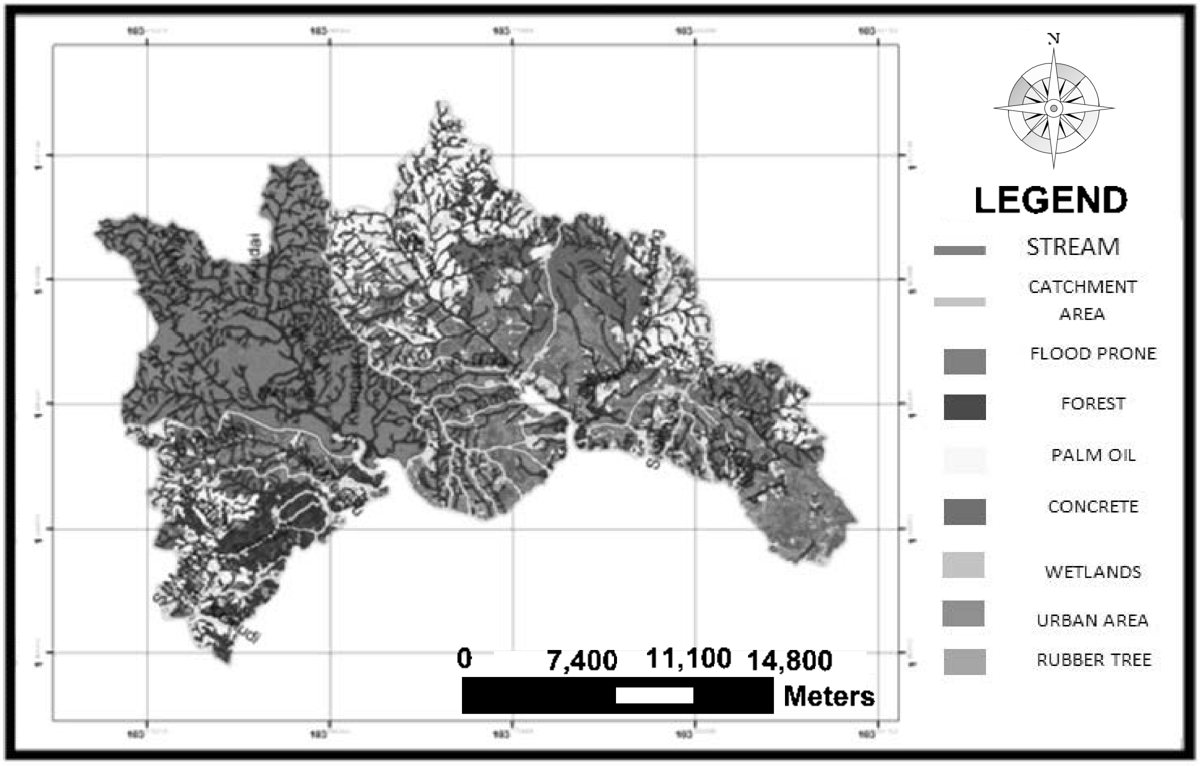

Fig. 5. Flood-prone map of of Johor Bahru city centre and Nusajaya.

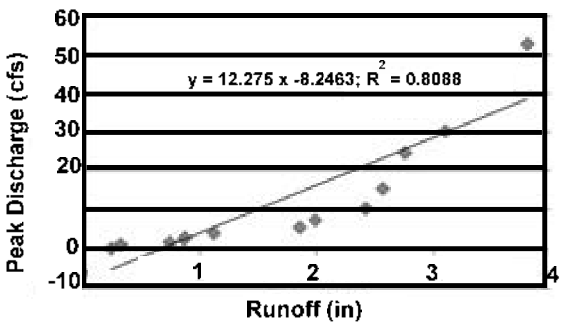

Fig. 6. Relationship between runoff and peak discharge.

Table 1. CN value for various land use.

Land use	CN
Water body	100
Mangrove	98
Oil palm	60
Coconut	65
Rubber	66
Forest	55
Urban	93
Paddy	79
Grassland	65
Open area	79

developed areas. The increase in impervious surface has generated high runoff and has high possibility of flooding.

3.1 Flood Prone Area Detection

Figure 5 shows the simulated flood-prone area map. Sungai Skudai watershed is shown to be in danger for overflow.

The determination of the flood-prone area is based on bankfull discharge of HydroCAD simulation with the peak discharge estimated from the SCS-CN model. Result shows that Plentong area is classified as flood-prone area. A study conducted by Badrul Hisham et al. (2009) also has classified Skudai and Plentong River as flood-prone area. Thus, this could be used in validate the produced result.

3.2 Runoff-Peak Discharge Relationship

Figure 6 shows there is a significantly positive correlation between runoff and peak discharge.

Regression analysis used generates an equation and to describe the relationship statistically between different variables (Jusoff et al., 1999; Fasinmirin et al., 2006; Al-Sabhan et al., 2003). Correlation between these two variables is strongly justified with the regression R^2 of 0.808. The increase of runoff is strongly influenced by peak discharge. Land-use of the catchment area such as urban area, open area and concrete surfaces exert high runoff that eventually create possibility of causing overflow during heavy rainfall events.

4. Conclusions

The SCS-CN model is suitable to be used to identify flood-prone areas as it has successfully delineated catchment areas of Skudai River and Plentong River. The land use of the study area catchment by maximum likelihood produced reasonable results with overall accuracy of 83.84 %. The land use map is then used to determine curve number CN of watersheds of Nusajaya and Johor Bahru within Iskandar Malaysia. One the CN for each watershed is estimated, the runoff of each watershed is obtained to produce peak discharge.

It is suggested that to improve the flood-prone identification results, land-use map with better resolution and site-specific soil type should be used.

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Symbols and abbreviations

A_m	drainage area
CN	curve number
F_p	pond/swamp adjustment factor
L_a	initial abstraction
P	rainfall depth
Q	runoff
Q_e	unit peak discharge
Q_p	peak discharge