An Automated Flood Detection Mapping Based on RADARSAT-2 Satellite Image through Ensemble Classification Approaches

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Key words: RADARSAT-2, Multispectral imagery, flood detection, Taguchi, rule-based classification.

SUMMARY

Floods are considered as one of the most destructive natural disasters, globally. Preparation of an actuate flood inventory map is the basic step in flood disaster management. Flood detection is yet significantly complex process due to the presence of cloud coverage in the tropical areas. Moreover, the most available techniques are expensive and time-consuming. Therefore, in the present study an efficient approach is presented to identify the flooded areas by means of RADARSAT-2 imagery. The proposed framework initially employs a RADARSAT-2 satellite image captured within a flood occurrence to map the flooded areas. Both RADARSAT-2 and Landsat image images were classified based on object-oriented technique which is a rule-based method. Image segmentation prior to classification was executed to distinguish the boundaries of various dimensions and scales of objects. The Taguchi method was applied to optimize the segmentation parameters. After the completion of segmentation, the rules were defined and the images were classified. The Landsat image was categorized into three classes of vegetation, urban and water bodies, while the RADARSAT-2 image was only classified into one class of water. Finally, the results of classification were estimated through a confusion matrix. The overall accuracy results derived from the classified maps, based on Landsat imagery and RADARSAT-2, were 93.04 and 89.18, respectively. As a result, the location of flooded areas were determined and mapped by subtracting the two classes of water bodies from these images. In this research, the combination of techniques and the optimization approach were applied as a pioneering approach for flood detection. The flood inventory map which was obtained by using the proposed approach is showing the efficiency of the methodology which can be applied by other researchers and decision makers to construct the flood inventory maps.

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1. INTRODUCTION

In recent years, floods occur with increased frequency from one year to another around the world. They force huge damages to belongings and in some circumstances even consequence in lost lives. A rapid and efficient reaction by rescue teams can considerably decrease the damages (Tehrany et al., 2013c). To have rapid response, fast and precise flood detection is required. To delineate flood endangered areas, susceptibility, hazard, and risk mapping should be done (Ip et al., 2006; Tehrany et al., 2014b). The basis of the mentioned analysis is constructed by the recognition of the flooded locations (Pradhan et al., 2014). Moreover, the precision of the flood inventory has direct impact on the generated susceptibility and hazard maps (Tehrany et al., 2014a). Therefore, the used method to collect the flood locations should be significantly precise. Another aspect is related to the requirement of rapid flood detection analysis (Brakenridge et al., 2003). The reason is, flood will not be stayed for long time in an inundated area and consequently very short time is available for the researchers to map all the locations. Definitely field work is not appropriate choice for such analysis due to the challenges and difficulties in the site, and the long time required. Traditional hydrological methods such as gauge and discharge measurements cannot be used to monitor and map the flood locations due to the temporal and spatial heterogeneity of large wetlands (Martinez and Le Toan, 2007). Generation of various numbers of satellites and sensors made revolution in monitoring, evaluating and predicting the natural disasters (Hirpa et al., 2013). Considerable improvements in flood detection have been made due to increased data collection rates, higher sensor resolution, the development of change detection algorithms, and the incorporation of remote sensing techniques (Gillespie et al., 2007).

Visual interpretation was one of the most famous methods to detect the flood locations in many years ago. Oberstadler et al. (1997) investigated the efficiency of the visual interpretation method and a European Remote Sensing (ERS-1) satellite data analysis with automatic classification techniques to derive the flood boundary. Their achievements showed that the visual interpretation could produce more accurate results compare to satellite analysis. However, the reason was related to the coarse resolution of the satellite data and weakness of the technology and computing software at that time. Recently, the accessibility to the wide range of software, very high resolution satellite imageries, active and passive sensors, facilitated the data collection, flood analysis and mapping within few hours (Auynirundronkool et al., 2012). On the other hand, now day's researchers consider the visual interpretation as time consuming, inaccurate, and costly method. This method is based on the expert knowledge and therefore it can contain some errors (Chambenoit et al., 2003).

It is evident that optical imageries are not suitable to be used in flood detection applications (Pradhan et al., 2014; Sanyal and Lu, 2004; Siyahghalati et al., 2014). Therefore, SAR imagery offers a huge potential for flood studies (Elbialy et al., 2013; Youssef et al., 2014). Various techniques were assessed by the researchers to map the flooding and each has some pro and cons (Horritt et al., 2001; Mason et al., 2007; Pulvirenti et al., 2011). Threshold segmentation algorithm or histogram thresholding is a simple but broadly used and effective method to create a binary image (Pulvirenti et al., 2011). Cunjian et al. (2001) utilized threshold segmentation algorithm to map the flood extent from RADARSAT-1 imagery in Dongting area of Hunan province. The performance of thresholding procedures for floodplain recognition using SAR sensors depends on the contrast between the flood and non-flood regions. Therefore, it is sensitive to the low-contrast images. Other weak points of this method are it is specific for each satellite scene, it is usually based on the visual interpretation, and its procedure is manually and time consuming (Pulvirenti et al., 2011). Active contour modeling is another method that can be used to map the flood extent in an area. Mason et al. (2007) applied this method on single-frequency, single-polarization SAR to map the flood locations in Thames west of Oxford, U.K. This method had an advantage that it decreased the noise due to SAR speckle. However, the researcher should have a priori knowledge of image statistical properties to use this method. Moreover, it gets stuck in local minima and produces inaccurate results when the initial contour is chosen simple or far from the object boundary.

Flood area extraction from multipass Synthetic Aperture Radar (SAR) data can be implemented via amplitude change detection techniques or generation of the coherence map (Nico et al., 2000). Amplitude change detection method works by comparing two SAR images of the same scene, one captured before and the other during or immediately after the flood. Subsequently, the water-filled zones can be detected by looking for decreased backscatter regions. The drawback of the amplitude change detection techniques is related to the difficulty and significant time required for the classification of at least two SAR data (Nico et al., 2000). On the other hand, to produce coherence map, SAR interferometry should be done which is often hard to be understood and complex to be interpreted (Jebur et al., 2013a, 2013b). To generate the coherence map some other difficulties and disadvantages can be seen. For instance, ground data and two precisely co-registered SAR images are needed to produce coherence map (Brisco et al., 2013). The ground data is required in order to distinguish flooded areas from other low-coherence zones. Furthermore other types of coherence lowering processes, such as vegetated field or forests can mislead the results.
In radar imagery paddy fields, mountains and all the water bodies also appear as dark or black (Pradhan et al., 2014). So we need a method that can discriminate between the flooded areas and other objects. Hence, current research aims to overcome some of the drawbacks in exist methods and produce more reliable and precise technique to detect the flood locations. The purpose is to perform change detection but not using two SAR imageries. A SAR imagery which was captured during the flood occurrence will be used as it can penetrate the cloud cover and record all the objects on the terrain surface. Furthermore, a cloud-free Landsat imagery will be used which was recorded before flooding. In this research free Landsat data was used to produce the required information. It was explained that in SAR imagery various features such as roof of the building, paddy filed, water bodies, and etc. will be appeared as dark and subsequently all will be classified as one class. However, using object-oriented rule-based classification method these objects will be

discriminated as it utilizes the additional characteristics of the objects such as texture, shape and etc. (Tehrany et al., 2013a; 2013b). Using Landsat imagery, the class of water before flood occurrence will be recognized and classified which will be used in change detection. On the other hand, using very high resolution RADARSAT-2 data and through rule-based classification all the water bodies will be extracted. Changes between two classes of the water bodies, derived from two images will represent the flood locations. Therefore, it can be stated that there are two steps in this procedure; 1) recognizing water versus non-water regions before and during the flood occurrence, respectively; and 2) comparing the regions categorized as water or non-water before and during the flood to detect which areas have been flooded.

2.0 APPLICATION SITE

In this research Kelantan was selected as a testing study area to examine the efficiency of the proposed method to detect the flood locations (Fig. 1). Kelantan is situated in Peninsular Malaysia, and is bordered in the east by the South China Sea. A destructive flood occurred in December 2014 in this area due to the heavy precipitation.

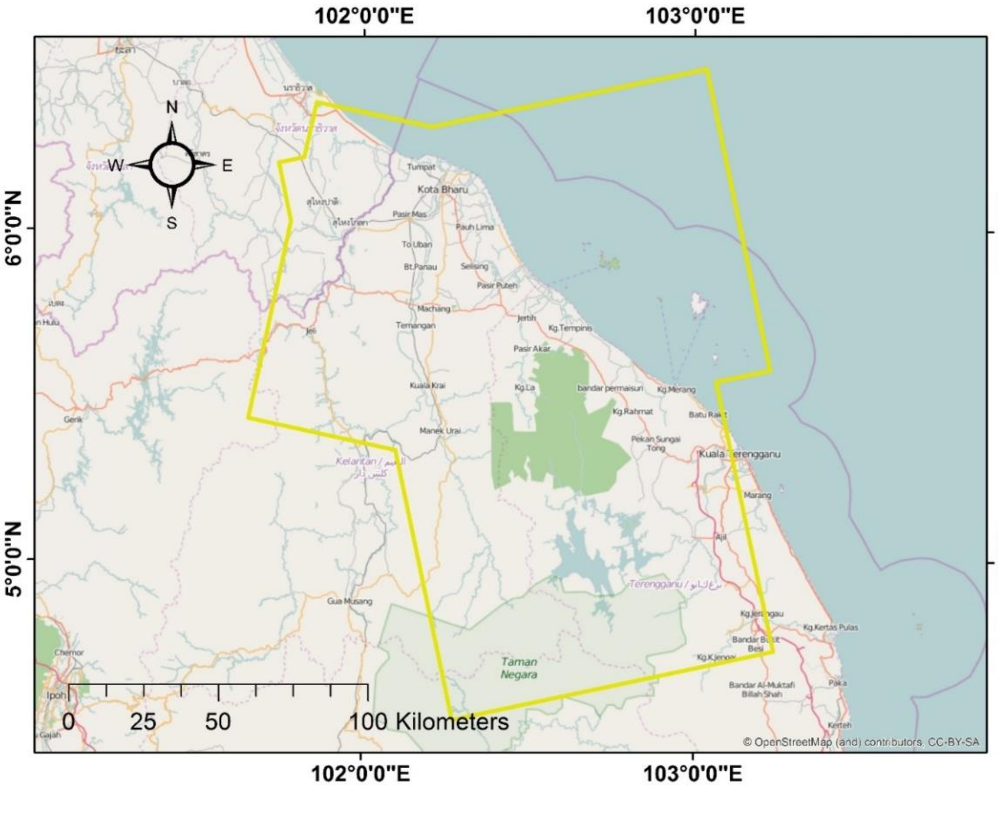

Figure 1: Location of study area

3.0 DATA AND METHODOLOGY

Two data sources were utilized in this research; SAR which was captured during the flood, and Landsat imagery which was recorded in August 2014 without flood occurrence. The SAR data used in this research was captured by RADARSAT-2 satellite from 12th November 2014 to 29 December 2014. Landsat imagery was acquired prior to the flood event which had 30 m spatial resolution with 15m panchromatic band (Fig. 2). The general methodology which was implanted in this study is shown in Fig. 3.

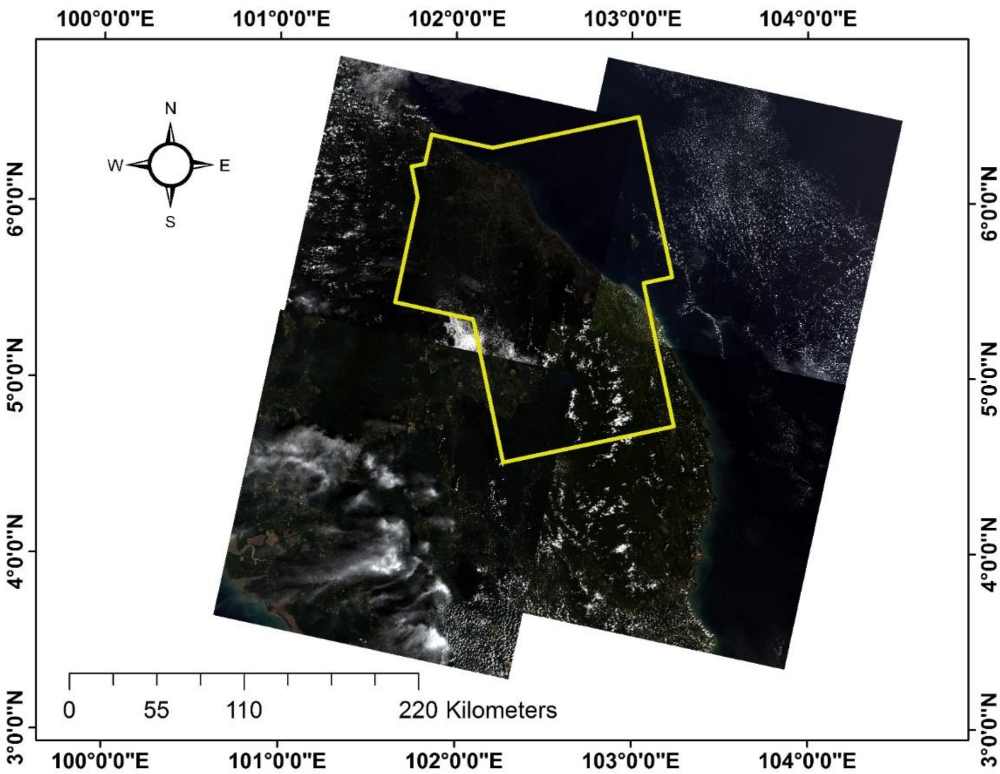

Figure 2: Landsat 8 image for the study area

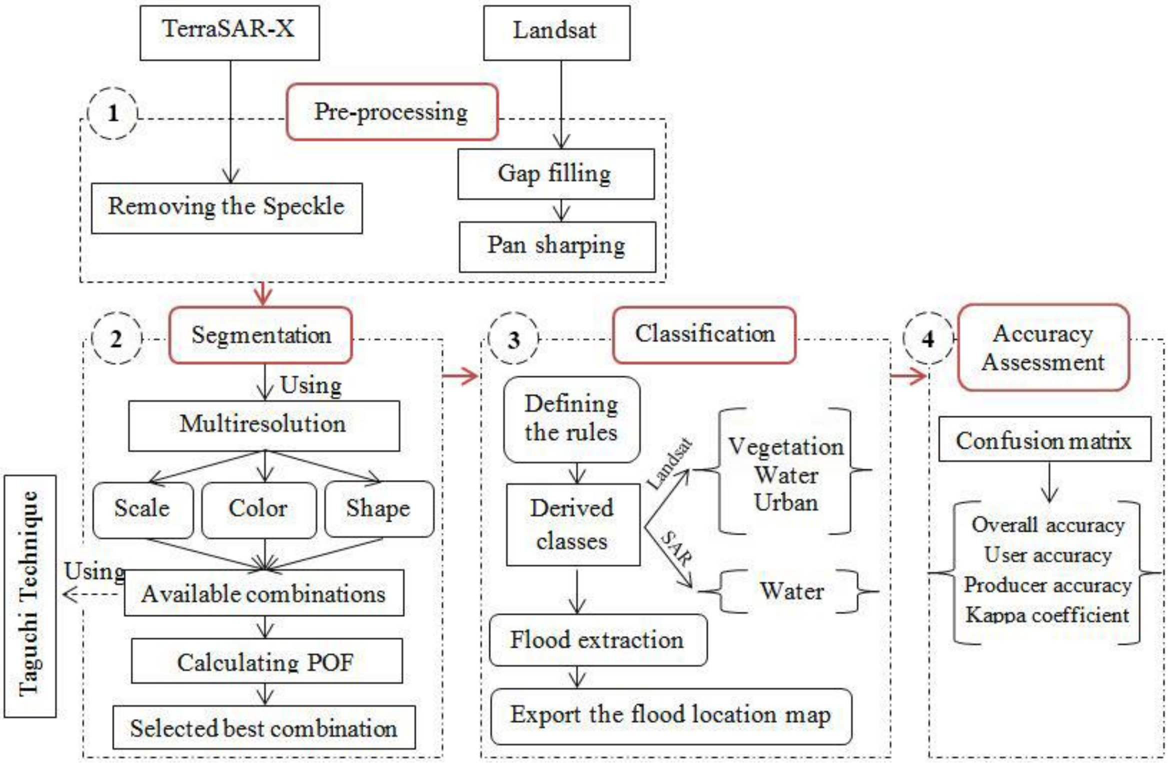

Figure 3: Overall methodological flow chart developed for the ensemble classification approach

4.0 RESULTS AND DISCUSSION

First, three parameters such as scale, color, and shape, were used and a total of 243 combinations were defined by following the methodology as given in Fig. 3. However, using Taguchi optimization technique, the number of these experiments reduced into 25 experiments. Table 3 represents the choices of experiments (available combinations) for segmentation parameters in addition with the measured POF for each combination. These two combinations were the optimum segmentation parameters for two dataset. The generated segmentation maps can be seen in Fig. 4.

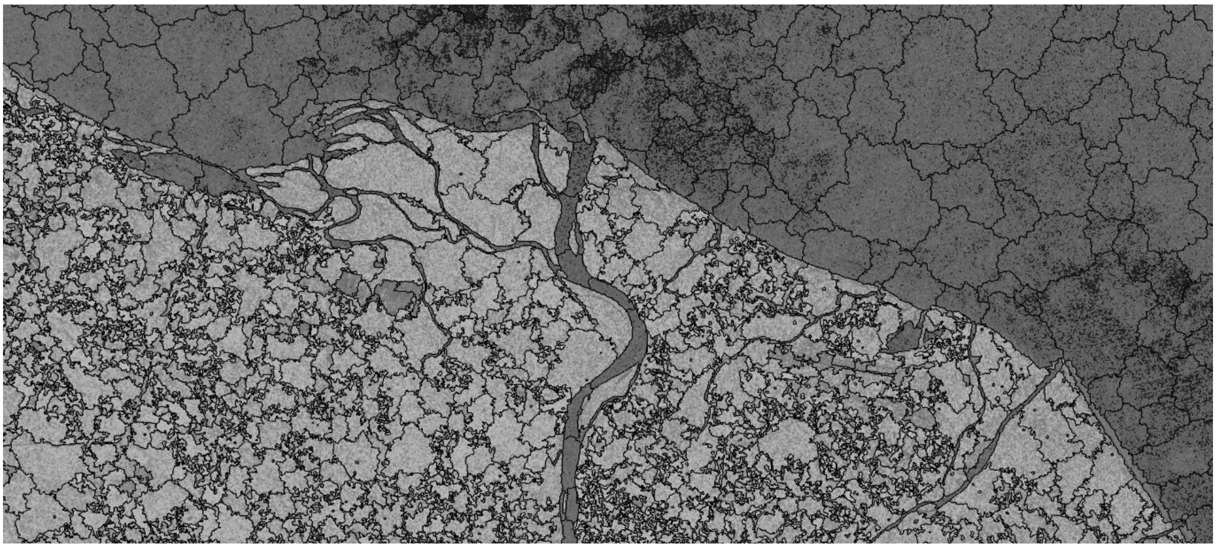

Figure 4: Segmented SAR image

It can be seen that the boundary of the objects were recognized very precisely using the determined optimum segmentation parameters by Taguchi technique. The results also represented the efficiency of the multi-resolution segmentation approach.

Next, by using the results of segmentation and the defined rules both images were classified. Fig. 5 illustrates the classified map of the RADARSAT-2 which contains two classes of water bodies and non-water bodies.

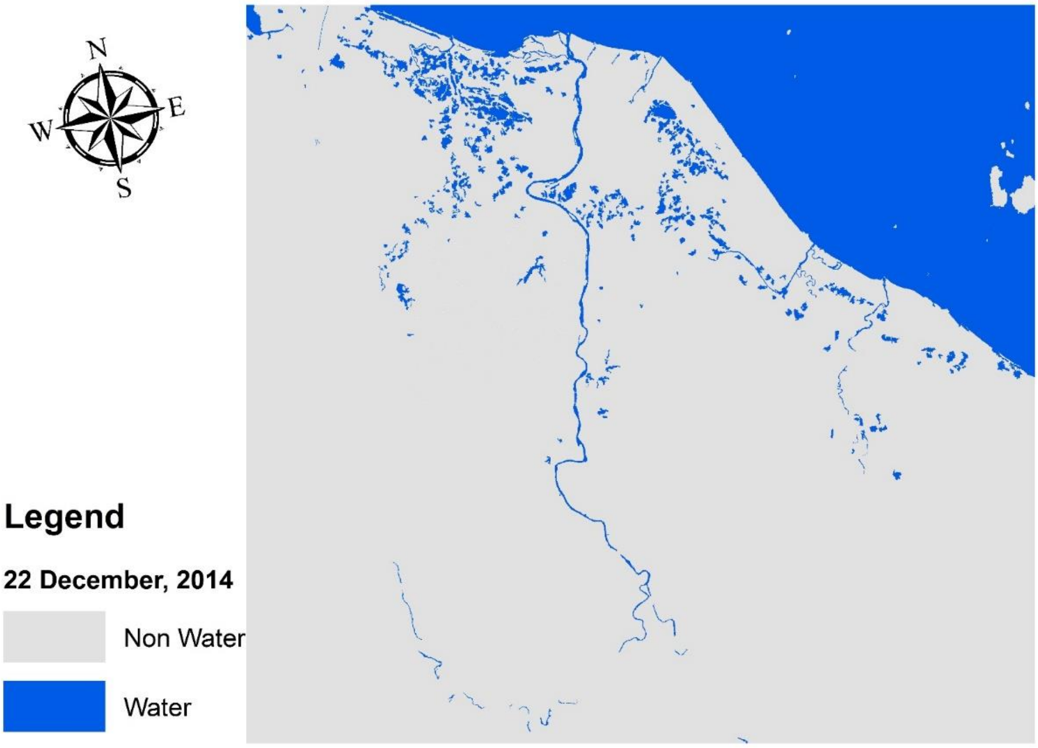

Figure 4: Extracted water areas from the RADARSAT-2 image

Visually it can be seen that the extent of water bodies in the classified RADARSAT-2 map are flooded regions. Hence, by subtracting the two classified water bodies, the locations of the flooded areas were determined. Fig. 5 illustrates the detected flood locations in current study area.

Fig. 5 shows that most of the affected areas by flooding which is mostly covered around the northern part of the study area. In order to examine the efficiency of the proposed method and to evaluate the generated flood inventory map, confusion matrix was measured. Tables 4 and 5 listed the confusion matrix results for the classified maps of the RADARSAT-2 and Landsat respectively.

Table 1: Confusion matric for RADSARSAT-2 image

Classes	Producer accuracy	User accuracy
Water bodies	95.03	93.92
Non water bodies	92.6	89.36
Overall accuracy	89.18	
Kappa coefficient	0.84	

Table 2: Confusion matric for Landsat 8 image

Classes	Producer accuracy	User accuracy
Water bodies	95.14	90.74
Vegetation	93.06	99.88
Urban	90.61	81.92
Overall accuracy	93.04	
Kappa coefficient	0.77	

The acquired overall accuracy for the classified maps of the RADARSAT-2 and Landsat were 89.18 and 93.04 respectively. It represented the efficiency of the rule-based in discriminating between the objects and hence producing accurate classification maps. Moreover, the kappa coefficients were 0.84 and 0.77 for RADARSAT-2 and Landsat classified maps respectively. As it can be seen in both accuracy assessment results, all the user and producer accuracies are reasonably high, indicating the reliability of the generated classes. Since the flood location map was derived by subtracting the two derived water bodies, their precision have direct impact on the precision of the derived map. Confusion matrix showed that both water bodies had high producer and user accuracies; therefore, it proved the reliability of the final generated flood location map. It can be concluded that the proposed methodology provided an easy, rapid and reliable procedure to map the flood locations with low cost. Therefore, this method can be used by the researchers in order to provide the flood inventory which is the basis of susceptibility, hazard and risk analysis.

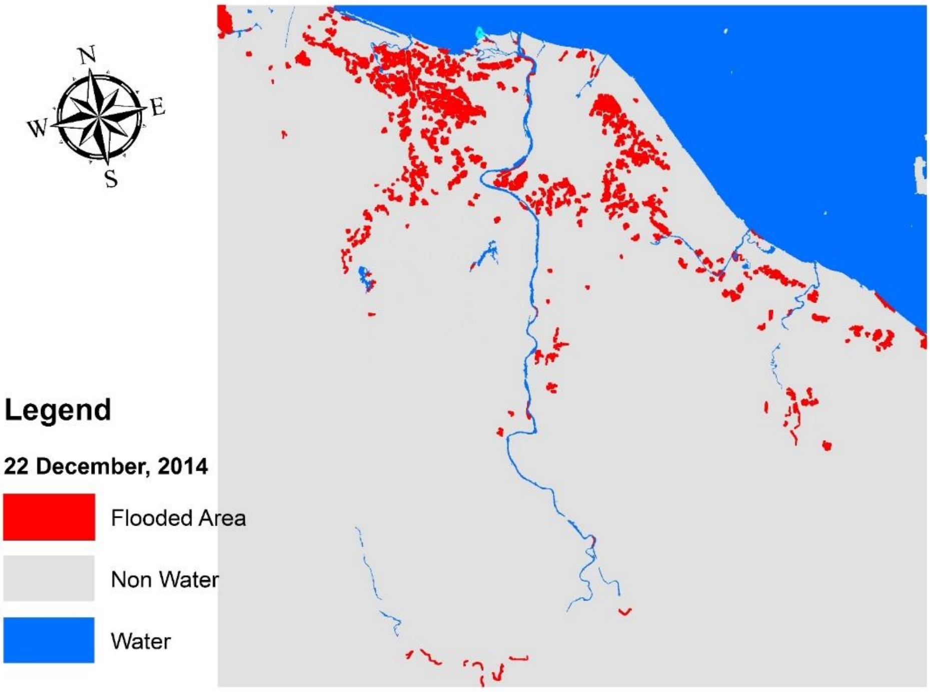

Figure 5: Map of the study area with detected flood locations i.e. flooded areas

5.0 CONCLUSION

Flood detection and producing the inventory map are very important for natural hazard assessment and flood prevention in tropical areas. Very high resolution active sensors made revolution in hazard studies which could overcome the weak points of optical sensors during the flooding. The current research was focused on efficient method for flood mapping, with the aim of enhancing and facilitating the traditional flood detection methods. Some of the traditional methods are considerably time consuming and costly which require significant work. In this study using only two datasets and simple analysis, the flooded areas were detected precisely and rapidly. Kelantan River Bason, Malaysia was chosen as a testing study area due the frequent flood occurrences in this state. RADARSAT-2 data was utilized to extract the water bodies during the flooding using object-oriented rule-based classification method. Furthermore, Landsat imagery was captured from the time that no flood has been occurred in the study area. From Landsat imagery, using the same classification technique, water bodies were mapped and subsequently subtracted from the RADARSAT-2 derived water bodies. The remaining water bodies represented the flooded location in the study area. Taguchi optimization technique, multi-resolution segmentation and the rule-based classification enhanced the quality of this study and speeded up the processing. The precision and reliability of the proposed method was examined by confusion matrix and the acquired accuracies proved the applicability of the proposed method for flood inventory mapping generation. The derived maps can be used by the planners and researchers to perform further research on flood susceptibility, hazard and risk mapping.

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BIOGRAPHICAL NOTES

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