APPLICATION OF SPOT5 SATELLITE IMAGE AND GIS FOR UPDATING ROAD NETWORK: TOWARDS BUILDING LANDSLIDE SPATIAL DATABASE

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ABSTRACT: Rapid development in urbanization is usually followed by development in transportation network. As the consequence, latest developed road networks are not found on the existing topographic map. As the topographic map-derived road network is not updated in short period, it is important to shorten the map updating cycles. SPOT 5 satellite image offers a cost effective way for updating the map compared to a conventional mapping method. The image, acquired in 2005, is used for updating road network on topographic map scaled at 1:50000, sheet 74, issued by JUPEM which was derived from aerial photograph taken in 1981. The road connecting Simpang Pulai cross and Kampung Raja, Cameron Highlands, is selected due to its considerably rapid development and susceptibility to landslide. Since most landslide occurrences take place along the road, updating road map as part of landslide geo-database becomes necessary. SPOT5 image is registered into Malaysian Coordinate System, RSO, to conform to the existing registered topographic map. Both image classification and on screen digitization methods are used to extract road network feature. The latest method is applied to complement to the first one in case of facing uncertainty in image classification. The quality of extracted road network from image classification is discussed. The extracted road network is stored into landslide spatial database. In regard to landslide aspects, features such as barren land, vegetation coverage, are also extracted. DEM derived from topographic map is used to generate slope risk map. GIS analysis is performed to locate high risk areas that prone to landslide based on two criteria. Those areas having high risk slope (20^0-35^0) and occupy barren/un-vegetated land are considered as high risk area. From this study, only 0.1% of areas occupy high risk locations. Some of which is located at existing slope failure area at Pos Slim.

Keywords : SPOT 5, road network updating, GIS, landslide

1. INTRODUCTION

The availability of earth imaging satellites, such as Landsat (30 meter), SPOT (10 – 20 meter) and high resolution satellite images such as Quickbird and IKONOS (0.61 and 1 meter) have gradually reduced dependency on conventional methods of updating road network, such as aerial photogrammetry and terrestrial survey. SPOT provides moderate resolutions and economic images for this purpose. One scene of SPOT image covers 60km x 60km area. The last two satellite images offer highest resolution images. However, for updating road network in rural area, they are considerably expensive. SPOT 5 belongs to the latest generation of SPOT missions with significant improvements in terms of on-board instruments and autonomous system of positioning and attitude control that will enable a high absolute location accuracy (SPOT-IMAGE, 2002).

Road network promotes economic development of district/regional trade, tourism, etc. The newly constructed roads usually do not exist in the existing topographic map. As for instance, the road connecting Simpang Pulai and Kampung Raja does not exist on JUPEM (Malaysian Surveying and Mapping agency) topographic maps sheet 3562 and 3662. This can be understood since the topographic maps were generated from aerial photogrammetric survey taken in 1981 while the road was constructed in 1994. Updating the map usually is not performed in a short period. The lack of present information of road networks on the topographic maps can be overcome by updating it using satellite images.

In most Asian road networks, they are passing through the undulating terrain with steep slopes where landslides are very common in these areas. There is also a high probability of slope failure due to either road construction work or cut slope (Hazarike et al., 1998). An integrated geo-spatial database for road network and risk assessment can be built using GIS (Geographic Information System), incorporating both topographic maps and SPOT5 satellite image. This will enable assessment of high risk areas, particularly areas that are susceptible to landslide.

As the study area, the road connecting Simpang Pulai cross and Kampung Raja junction is selected. *Figure 1* shows the topographic map overlaid by old road network map. The picture shows that the road was ended at point A from Simpang Pulai cross and at point B from Kampung Raja junction.

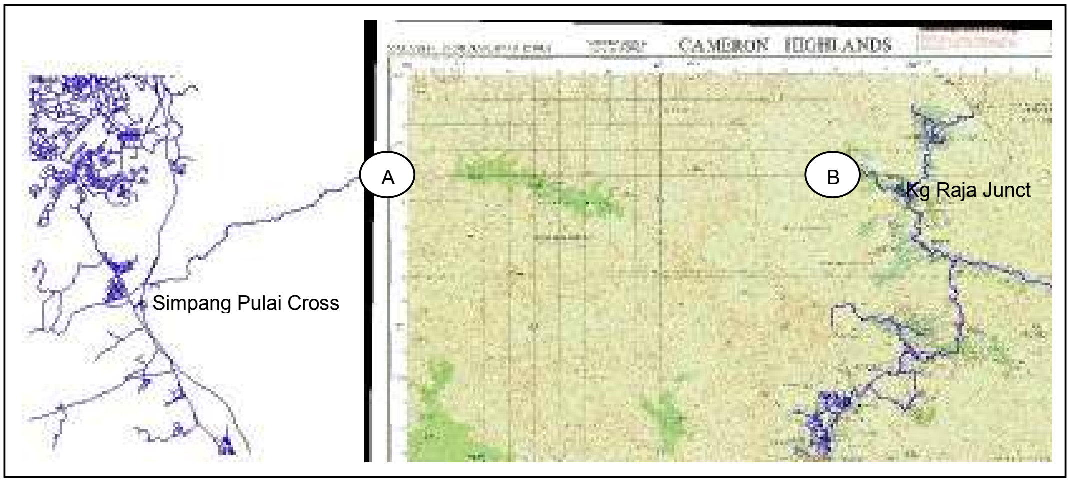

Figure 1. Study Area: the road connecting Simpang Pulai cross and Kampung Raja junction

In addition, slope failures and landslides are commonly found along this road. This leads to the need of building geospatial database for road network and risk assessment. *Figure 2* shows GPS (Global Positioning System) tracking of the road and confirms on-site occurrence of either landslide or slope failure on the site.

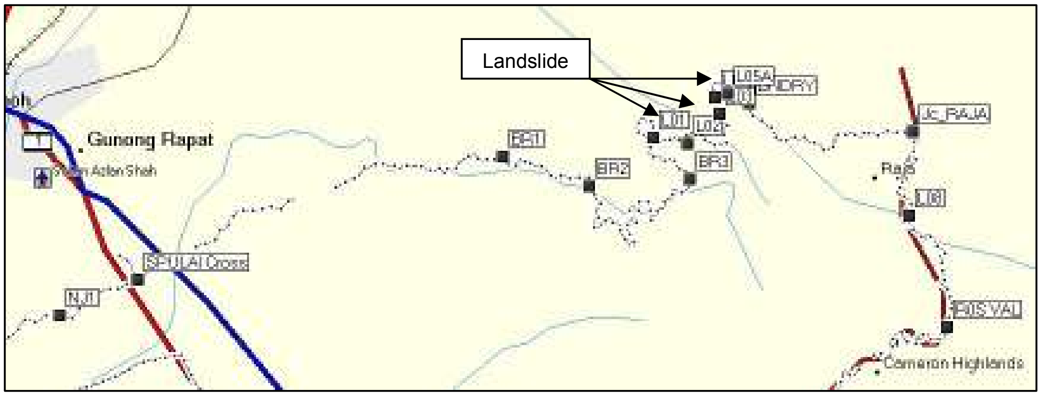

Figure 2. New roads tracked by using handheld GPS receiver

Extraction of road network from satellite images has been commonly applied. The method of which can be grouped into three, conventional or on-screen digitization (Yagoub, 2003), (Hazarike et al., 1998), semi automatic (YUN and KeiichiUCHIMURA, 2008) and fully automatic segmentations (Easa et al., 2007; Ekpenyong et al., 2007; F.Ameri et al., 2007; Klang, 1998; M. Gerke et al., 2003; Wan et al., 2007; Zhang and Couloigner, 2005). Automatic road segmentation mainly involves Artificial Neural Network (ANN), fuzzy, wavelet and knowledge-based road extraction. The methods used in this study are on screen digitization and unsupervised image classification. Since the road of study area is not complex, both methods are selected due to their simplicity in steps of image processing.

The works of this study can be divided into two main works, namely, road network extraction and GIS analysis. Figure 3 and 4 show workflows of both main processes respectively.

2. MATERIAL AND METHODS

In this study, a multi spectral SPOT 5 satellite image and topographic maps were used. The image, dated 19 April 2005 with path/row 268/341, was provided by MACRES (Malaysian Centre of Remote Sensing). It mainly covers east part of Perak (Kinta District) and West part of Pahang (Cameron Highlands District). The 10 meter resolution image is sufficient for road network extraction. Among its available 4 bands, band 2 (red channel, 0.61-0.68µm) provide best channel for showing roads and barren land which are required for this study. In addition, it has significant contrast between vegetated and non-vegetated areas. This band supplies required spatial information for evaluating risk areas, such as vegetated and non-vegetated land covers, along road connecting Simpang Pulai to Kampung Raja junctions.

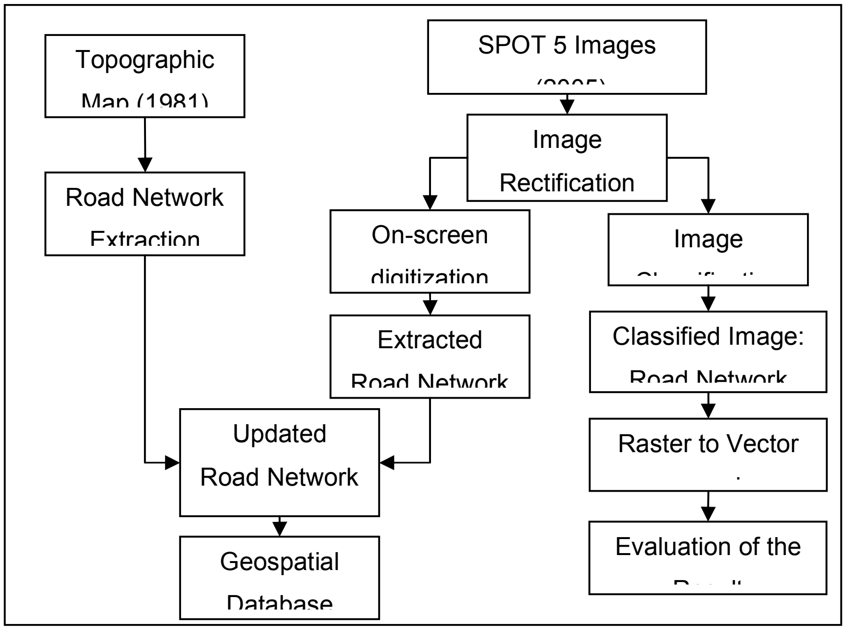

Figure 3. Road network extraction workflow

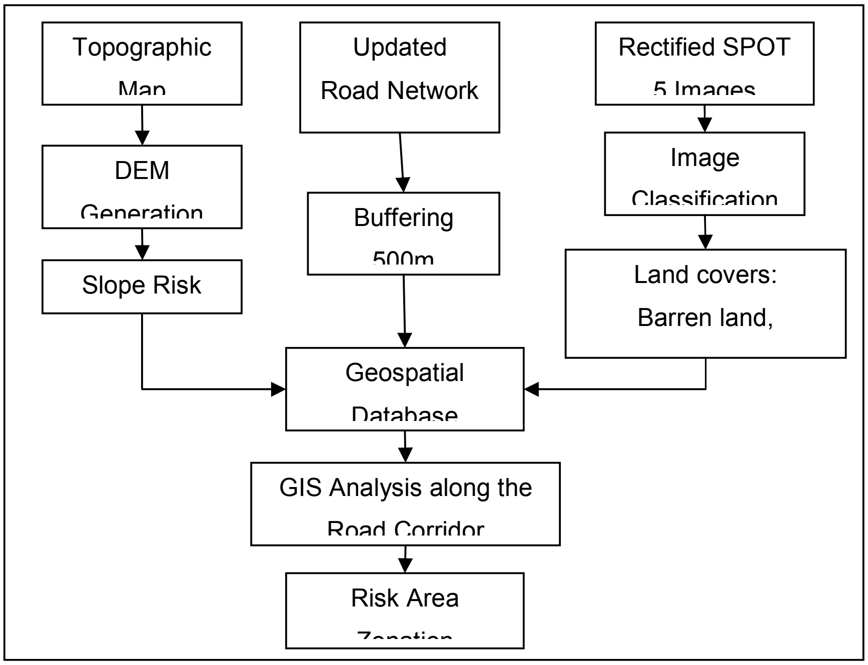

Figure 4. GIS analysis of high risk area along the road

In order to obtain information such as Digital Elevation Model (DEM) and existing (old) road network, topographic maps provided by JUPEM (Malaysian Surveying and Mapping Agency) were used. The maps include sheet 3562 and 3662. The information on the map was based on compiled aerial photographs taken in 1981. Latest revision was made to accommodate newly constructed road in 1994. From this point, it is apparent that updating road network on such topographic map becomes necessary.

2.1 Image Rectification

SPOT5 satellite image were simply rectified using re-projection facility in image processing software. There is no GCPs (Ground Control Points) used in rectification. This is because of the difficulties in placing GCPs evenly in such mountainous area as like this case. GCPs can only be measured at easily identified points along the road. In order to get a better result of rectification, it is required to collect GCPs at evenly distributed space over the entire area on the image using GPS. However, due to the limitation of the budget, image re-projection method is selected. The image is re-projected from original projected coordinate system, WGS 1984 UTM Zone 47N, into West Malaysian one, Kertau_RSO_Malaya_Meters. This step should be fulfilled first before extraction of any information from the image.

Re-projection means rectifying the satellite image so that it is conform to the reference coordinate system of topographic maps for further GIS analysis.

2.2 Image Classification

Image classification was performed by using unsupervised classification method. Ten classes were assigned. Band 2, which is red channel, was used for a main band in this classification process. This band has a good characteristic to identify road and bare soil which are required for this study. The features expected from this process are road network, vegetation type, water body, barren land. The latest was used in further GIS analysis. Region colour and name of classified features were assigned to enable better image interpretation. In naming the regions, both information from field survey and image enhancement by combining bands to get natural colour view (R=band 2, G=band 1, B=band 3) were used.

In GIS analysis, the format data of extracted road network is more preferable in vector format (shape file) rather than in raster format. Buffering and any extracting measurements are of GIS analysis in which the data in vector format is preferable. Image classification results in data in raster format. The extracted road network was converted into vector format using the facility in GIS software. Road patterns are evaluated and compared with those from actual satellite image and on-screen digitization. RSO projection system was assigned to layer created from image classification for further analysis in GIS environment.

2.3 Land Cover Classification

Figure 5 shows image classification result of band 1 (5a) and band 2 (5b). Band 1 clearly shows road network pattern while band 2 is dominated by vegetation coverage coloured in bright green. Open/barren land appears along side of the road coloured in brown. Road network is shown in red colour. For assessment of high risk area due to landslide susceptibility, only factors that contribute extreme (highest) risk will be considered, namely open/barren area. RSO projection system is assigned to these layers.

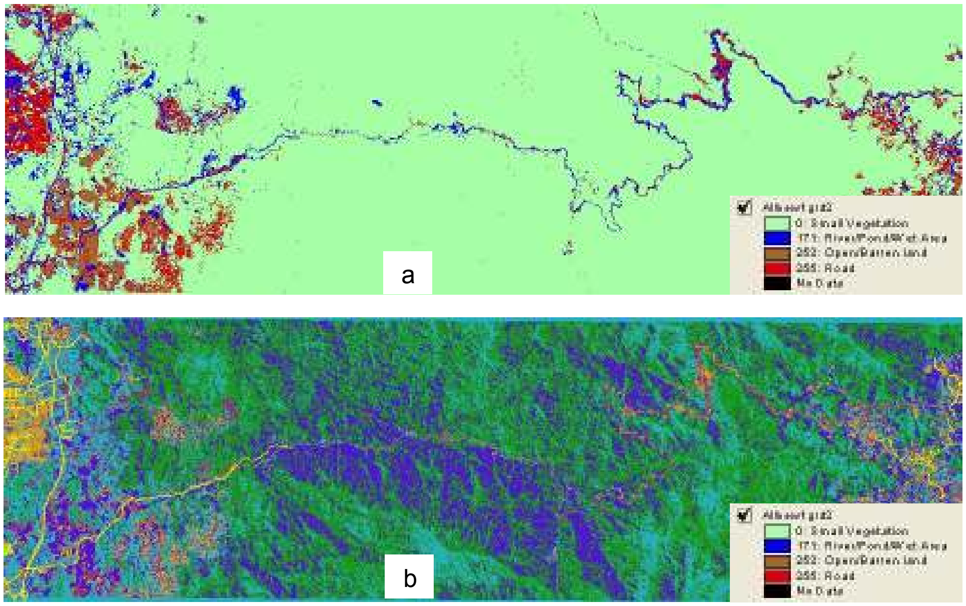

Figure 5. Land cover classification of band 1 (a) and band2 (b)

2.4 On-screen Digitization of Road Network

Using GIS software, road network was on-screen digitized by tracing the road from beginning to the end. Problem arises when the road can not be differentiated from the surrounding features. Such problems happen when the surrounding road is covered by thick vegetation (shown by white arrows (Figure 6a) or the road has the same spectral with nearby cut slope or slope failure. Materials and dust from slope failure areas cover the road. Such situations are shown in *Figure 6*.

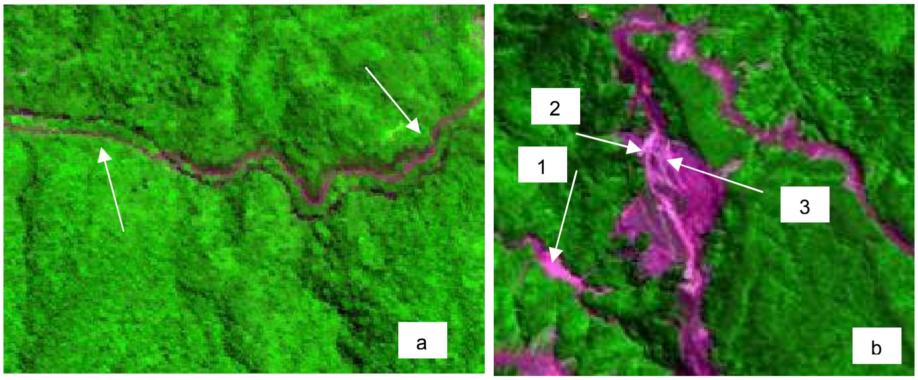

Figure 6. Thick vegetation (a) and material or dust from slope failure (b) causing difficulty in on-screen digitization

According to spectral values, three points on *Figure 5b* shows the closeness of digital numbers. *Table 1* shows respective spectral values of three points from three bands (Red, Green, Blue)

Table 1. Closeness in spectral values

	B1: Red Layer	B2: Green Layer	B3: Blue Layer
Point 1	100	240	253
Point 2	98	240	253
Point 3	103	238	253

During digitization, it is important to ensure that all vertexes are joined. Since the road connecting Simpang Pulai cross and Kampung Raja junction will be stored in geodatabase as one feature class, object snapping is employed to ensure all vertex points joined. In order to enable them working with other spatial data, RSO projection system was assigned to this feature class.

2.5 DEM Generation

Contour lines extracted from the topographic map were used for generating Digital Elevation Model (DEM) by using Triangular Irregular Network (TIN) interpolation method. This was done by using facility in GIS software. Figure 7 shows DEM of the study area overlaid by old road network. From the derived DEM, other spatial data such as slope risk and slope aspect map can be derived. In this study, only slope risk map was used for assessing high risk area that prone to landslide.

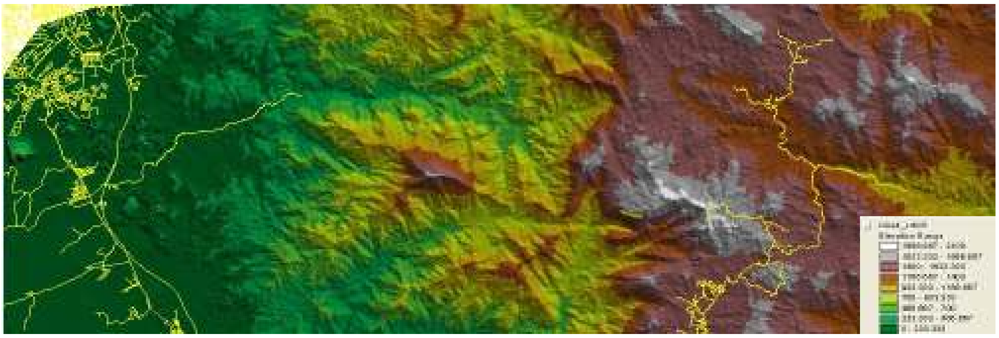

Figure 7. DEM of study area

2.6 Slope Risk Map

Slope risk map becomes important in assessing areas that are prone to landslide since there is a relation between landslide occurrence and slope angle. (Sharifah et al., 2004) reported that the number of landslide occurrence increase as the slope angel increase to 57^0. Beyond this slope, the number of slides is decrease. This means that slopes steeper than 57^0 are composed of very resistant rocks or there are too few pixels steeper than 57^0 to be statistically valid. Densities of landslide increase up to slope of 28^0, then decrease. The commonly accepted angel of repose for granular unconsolidated material is 35^0. In this study, slope angle is divided into three classes referring to (Sharifah et al., 2004) who investigated landslide at the same area, Pos Slim. The highest landslide densities occur in slope angels range from $20^0 – 35^0$. Lower densities are on slope angels 12^0-20^0 and 35^0-41^0. Lowest densities are on slope of less than 12^0 (due to low dip of sliding) and slopes of greater than 41^0. Figure 8 shows slope risk map derived from DEM.

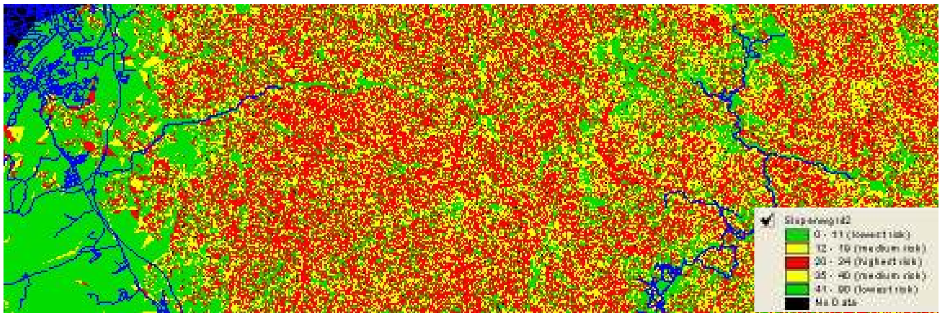

Figure 8. Slope risk map overlaid by old road network

2.7 GIS Analysis of High Risk Area along the Road

GIS analysis was performed to locate high risk areas that prone to landslide in a corridor along the extracted road based on high risk slope and barren/open land coverage.

a. *Buffering*

A 500m width corridor at both sides was defined for GIS analysis. Using buffering facility in Spatial Data Modeller Extension (Kemp et al., 2001), a buffer zone was created (Figure 9). These buffer zones were used for cropping all spatial data required for GIS analysis.

Figure 9. Buffer zones along the road

b. *Overlaying*

After all required geo-spatial data available, an overlaying process can be done to produce a risk map by combining slope risk and land use map. Overlying was done by using querying process.

The following requirements were inputted in querying formula:

$20^0 \leq$ Slope angle $\leq 35^0$
Land cover = 171 or Land cover = 253

The expected result would be a high risk area along the road corridor connecting Simpang Pulai cross and Kampung Raja junction.

3. RESULT AND DISCUSSION

3.1. Extracted Road Network

Road networks have been extracted from both on-screen digitization and image classification. The first method produced road networks that are conformed to the existing topographic map projection system, RSO. (see Figure 10).

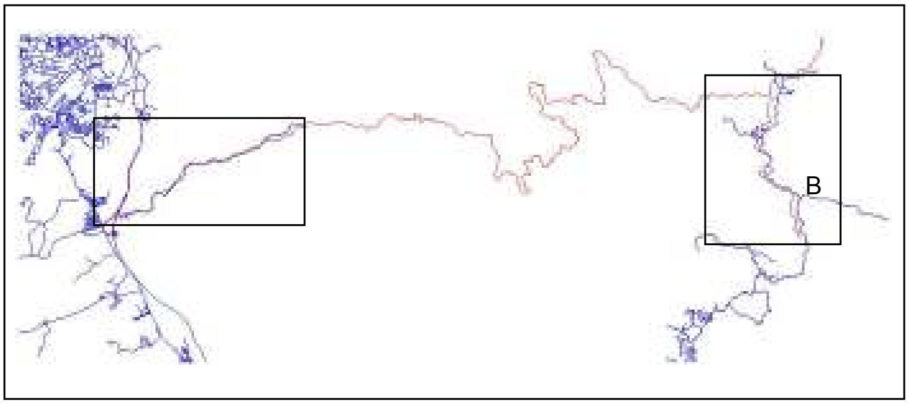

Figure 10. Road map extracted from on-screen digitization (red) overlaid on the old road network (blue)

If we take a look at box A and box B in Figure 10, the newly extracted roads shows different road alignment compared to old ones. From figure 11a, it is apparent that the different in both road alignments is caused by change in road alignment passing the ponds. Old road shows the alignment passing right side of the pond, while the new one passing the left side of the pond. Road alignments from GPS tracking consistently coincide with those from on-screen digitization. In case of different road alignment in Figure 11b, the causing factor is remained questioned. The quality of Image re-projection may be the only possible error source. Since road networks shown in Figure 11b are located at the corner part of one full image, the error may be from radial distortion. It is shown in Figure 12, denoted by red circle.

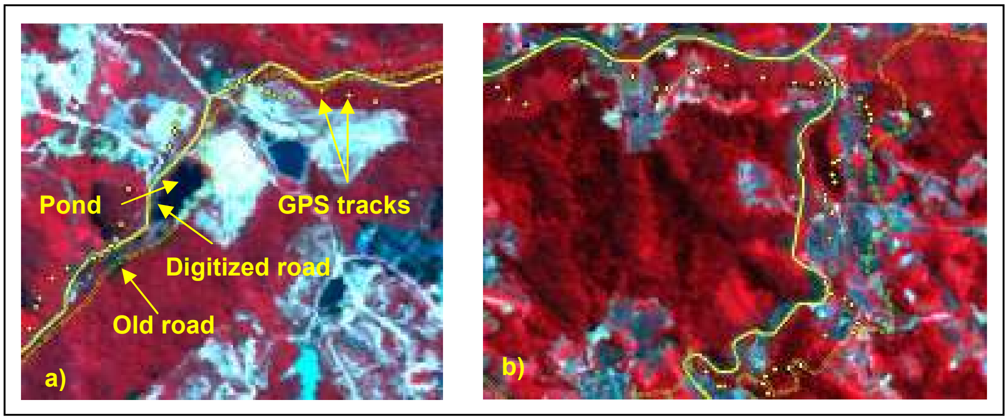

***Figure 11**. Road map extracted from on-screen digitization*

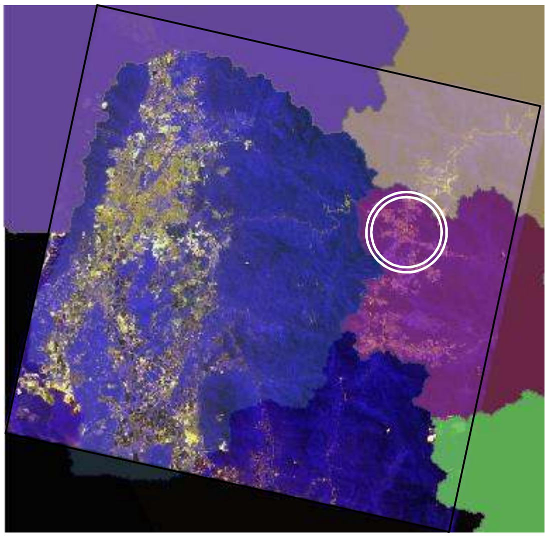

Figure 12. Preview of full scene SPOT image and the location of error in road alignment.

Road networks resulted from image classification is shown in Figure 13. The results seem to be confused with the objects other than the roads (shown by arrows). The objects are interpreted as buildings and open space/land. This is caused by the closeness in spectral reflectance as case in Table 1. After converting from raster into format, the road network map shows "noises" that may come from vectorized other objects. Efforts to remove the noise are needed either by manually removing or applying threshold values during image classification. In this study, these road networks are not involved in geo-spatial database due to complexity in removing the noises.

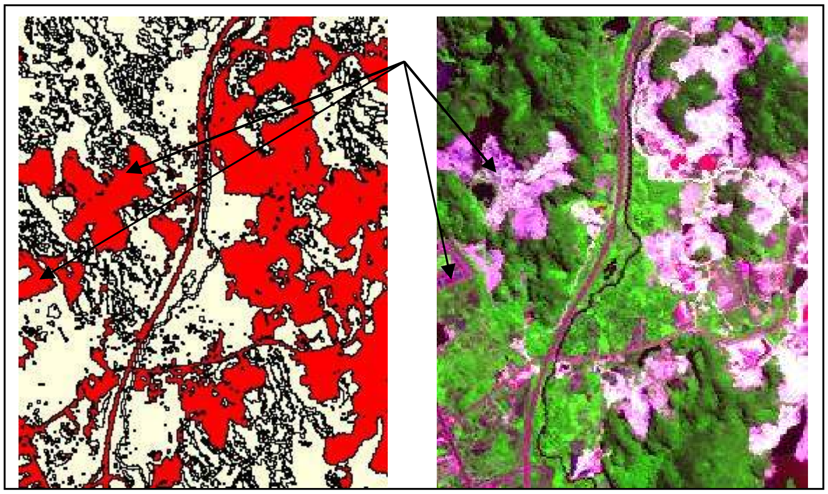

Figure 13. Road network extracted from image classification and its corresponding satellite image

3.2. GIS Analysis Result

Figure 14a shows high risk area overlaid by road corridor map to yield high risk area map along the road corridor. While Figure 14b contains land cover (which is only barren land area) overlaid by road corridor to yield barren area map along the road corridor. Overlying both spatial data and the road corridor yields (Figure 14c) would result is high risk map along the road (Figure 14d). The number of pixels occupying high risk area along the road corridor is 127 while the total pixel along the road corridor is 130.050. By comparing both values, the percentage of high risk area along the road corridor is 0.1%. Even though this value is considerably small for this preliminary GIS analysis, part of high risk areas agrees with the area where the landslide/slope failure occurs (Figure 14d). Figure 15 shows high risk area with the corresponding SPOT satellite image. High risk areas (shown in red dot) are located on landslide/slope failure locations. While on the right side of the picture, high risk areas occupy farming areas.

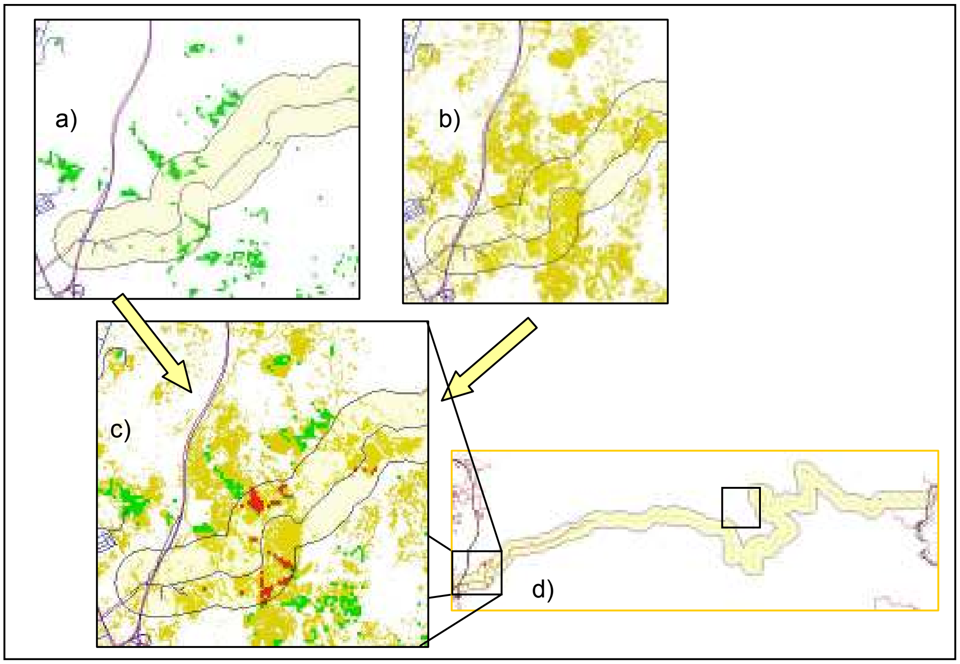

Figure 14. Overlaying in GIS analysis.

Figure 15. High risk areas at landslide/slope failure locations (red dot)

3 CONCLUSION

The major outcome of this research is the application of SPOT5 satellite image in updating road network map connecting Simpang Pulai cross and Kampung Raja junction. The extracted road networks, from on-screen digitization, have slight different compared to the previous/old road map on the topographic map. The differences may come from the change in road alignment and geometrical error of the sensor due utilization of image re-projection procedure. Site survey is necessary for both checking whether there is any road alignment change and performing measurement of Ground Control Points. The latest is needed to better rectify the image so that such geometrical error can be removed.

Preliminary GIS analysis has yielded high risk area along the road corridor that prone to landslide. Using two landslide affecting factors, barren land and high risk area layers, high risk areas can be identified. Some of the high risk areas are located where the landslide/slope failures occur. Some of them are located on farming area. The latest needs to be proven by site verification.

By preparing all extracted spatial data in a same projection system, that is RSO, and storing them into geodatabase file, it means that road network and landslide geospatial database has been initiated. Preliminary GIS analysis in this study has been an example of utilizing this geo-database.

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