Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

p-ISSN: 0972-6268
e-ISSN: 2395-3454

Vol. 16 | No. 1 | pp. 29-35 | 2017

Original Research Paper | Open Access

Effect of Upstream on Downstream Due to Spatio-temporal Land Use Land Cover Changes in Kelantan, Peninsular Malaysia

Mohd Talha Anees*†, Abdullah K.*, Nawawi M.N.M*, Nik Norulaini Nik Ab Rahman, Abd. Rahni Mt. Piah***, M. I. Syakir****, Mohd. Omar A. K.******

*School of Physics, Universiti Sains Malaysia, 11800 Minden, Penang, Malaysia
**School of Distance Education, Universiti Sains Malaysia, 11800 Minden, Penang, Malaysia
***School of Mathematics, University Sains Malaysia, 11800, Minden, Penang, Malaysia
****School of Industrial Technology, Universiti Sains Malaysia, 11800 Minden, Penang, Malaysia
†Corresponding author: Mohd Talha Anees

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 03-03-2016
Accepted: 16-04-2016

Key Words:
Flood
Landsat
Land use land cover
Remote sensing
GIS

ABSTRACT

The present study deals with the effects of upstream spatio-temporal land use land cover (LULC) changes on downstream by the use of Landsat and Google Earth data in Kelantan, Peninsular Malaysia. The study involves mosaic of multi-temporal satellite data of Landsat-5 TM of 2005 and Landsat-8 OLI_TIRS of 2015, which have been analysed visually. The study reveals that the effect of major spatio-temporal LULC changes of upstream can cause river overflows and flash flood at downstream. The major LULC changes noticed were decrease in dense forest 798.89 km^2 (5.30%) at up and midstream and mixed horticulture 263.34 km^2 (1.74%) at mid and downstream, while increase in forest (416.82 km^2) at midstream and scrub (190.62 km^2) at upstream due to transformation from dense forest. Furthermore, increment in uncultivated land (68.33 km^2) and palm oil (372.66 km^2) plantation activities at both up and midstream was observed. The accuracy assessment result of the study shows that study was accurate with overall accuracy of 91.4%.

INTRODUCTION

Among the natural hazards, flood (either monsoonal or flash flood) is the most common and devastating threat in Malaysia which affects thousands of people every year and causes the loss of life and economy (Ghani et al. 2009). Flash flood is caused by the combination of anthropogenic activities and topographic changes which results into high runoff and hence river's structural changes (Creutin et al. 2013, Špitalar et al. 2014). The effects of these factors on downstream flood are to be quantified to understand flood pattern and control thereof.

Land use and land cover (LULC) changes play a very important role in finding the causes of topographic changes which result land degradation (Eaton et al. 2008). It also provides invaluable information for managing land resource and their development (Al-Bakri et al. 2013). Upstream land degradation results increase in runoff and changes in river's geometry such as decrease in river depth due to sediment deposition and increase in stream power (Lecce 2013) at downstream.

Remote sensing and Geographic Information System (GIS) is very effective tool for initial studies. High resolution data can provide accurate results but in data sparse environment, the freely accessible data such as Landsat and MODIS are the better option to know the topographic changes. MODIS has some limitations such as its coarse resolution which limits its ability in detecting small changes (Jin & Sader 2005), which is necessary in detecting anthropogenic activities (Zhu & Woodcock 2014). While Landsat data have some advantages over MODIS such as long record of continuous measurement, spatial resolution, and near nadir observations (Pflugmacher et al. 2012, Wulder et al. 2008 and Woodcock & Strahler 1987). But its disadvantage is low temporal frequency and cloud cover problem. However, the mosaic of multi temporal images with less cloud cover can provide accurate results (Zhu & Woodcock 2014). Kibret et al. (2016) and Zhu & Woodcock (2014) used Landsat in their studies and concluded that the Landsat data are very useful in the analysis of spatio-temporal LULC changes.

There are two methods of classification of LULC which can be done by using remote sensing and GIS. The visual classification technique has advantage in terms of accuracy over automatic or supervised classification in heterogeneous LULC classification which is based on the expert knowledge (Zhang et al. 2014).

The main objective of this preliminary study of flood analysis is to get accurate results of LULC by analysing the freely accessible data through an integrated approach of remote sensing and GIS of whole Kelantan in Peninsular Malaysia. The analysis will lead the spatio-temporal LULC changes to find out the effect of upstream LULC changes on downstream of the area. The result of this study will be helpful in further enhancement of the technology and identifying the causes of downstream flood by using modelling techniques.

MATERIALS AND METHODS

Study area: The study area was located in the north eastern part of peninsular Malaysia between latitudes 4°33' and 6°14' North, and longitudes 101°19' and 102°39' East with total area of 15113.55 km^2 and highest elevation 2,187m (Mt. Tahan) at the Kelantan-Perak border (Fig. 1). The area was divided into upstream (Gua Musang), mid-stream (Kuala Krai, Jeli, Tanah Merah and Machang) and downstream (Pasir Mas, Pasir Puteh, Tumpat, Bachok and Kota Bharu) as shown in Fig. 1 to analyse spatio-temporal LULC changes in each stream. The length and breadth of the catchment is 187 km and 148 km respectively. The area has average annual rainfall is 2459.58 mm in last 31 years with a mean annual temperature of 27.5°C. The main rivers in the study area are Sungai Kelantan which divides after approximately 107 km from the mouth of basin into Sungai Galas and Sungai Lebir at midstream (Kuala Krai). Furthermore, Sungai Galas is divided into Sungai Balah, Sungai Tarang, Sungai Pergau and Sungai Nenggiri. The Nenggiri River originates in the south western part of the central mountain range while Sungai Lebir from Tahan mountain range. Other main rivers at downstream are Sungai Lemal, Sungai Meranri, Sungai Kemasin, Sungai Peng Datu and Sungai Pengkalan Chepa.

Methods: Topographic map was geo-referenced in ArcGIS 10.2. Area boundary and district boundaries were demarcated on the basis of watershed with the help of ASTER GDEM and topographic map of Kelantan. The area was clipped with the satellite data in the GIS environment to extract area's raster image. Spatio-temporal LULC change map of 2005 (Fig. 2) and 2015 (Fig. 3) were prepared in GIS environment through visual classification method on the basis of spectral reflectance of different classes.

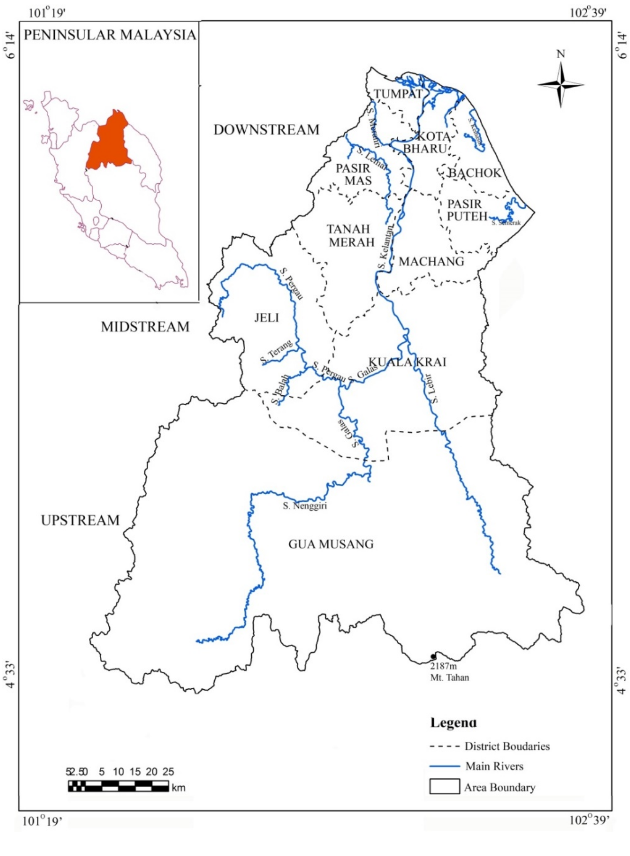

Fig. 1. Base map of Kelantan.

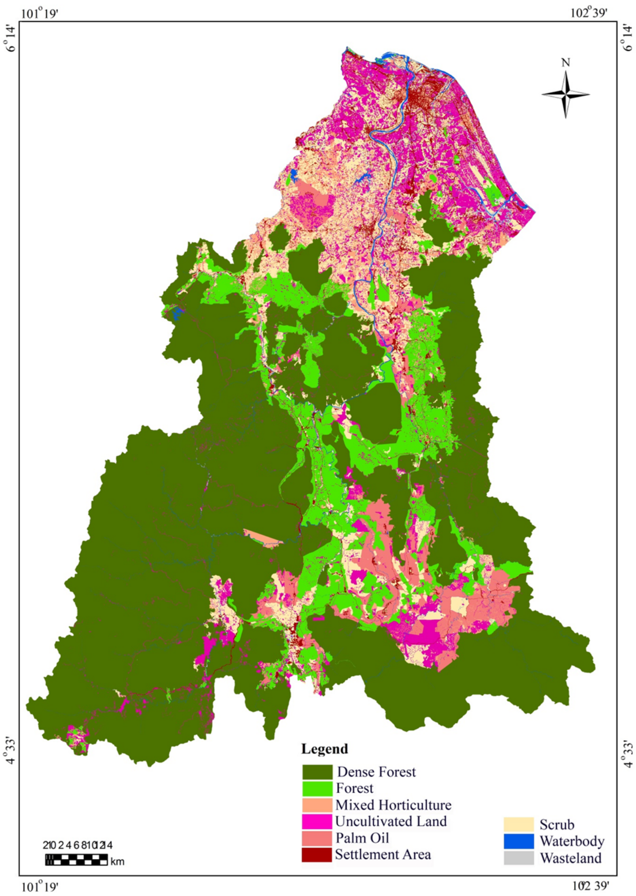

Fig. 2. LULC map of 2005.

Auto complete polygon tool was used to digitize LULC classes in ArcGIS 10.2. Nine LULC classes were identified and each class was assigned a unique code. Google Earth information was also used to delineate various LULC classes such as dense forest, forest, mixed horticulture, uncultivated land, scrub, settlement area, palm oil, water body and waste land.

Random ground truth points were taken in Google Earth of each class and then overlaid the points on visually classified map to know the accuracy. 100 points were taken of all the classes except wasteland (40 points) due to its low spatial extent and then manual accuracy assessment was done. Area (in square kilometre) and other calculations were carried out in ArcGIS 10.2 and MS Excel. Finally, both the maps (2005 & 2015) were overlaid together for the change detection analysis.

RESULTS AND DISCUSSION

Topographic changes at the upstream generally affect the downstream flow. The combination of these changes with high rainfall can drain the loose sediment into the river and hence deposited in it where the velocity of stream reduced. As a result, reduction in river depth and then overflow at the river bank at the downstream causes flash flood. The flood analysis of Landsat 5 TM (2005) and Landsat 8 OLI_TIRS (2015) were used to analyse the spatio-temporal LULC changes at upstream (8235 km^2), midstream (5004.01km^2) and downstream (1874.53 km^2). The results of visually interpreted classes from satellite images are as follows:

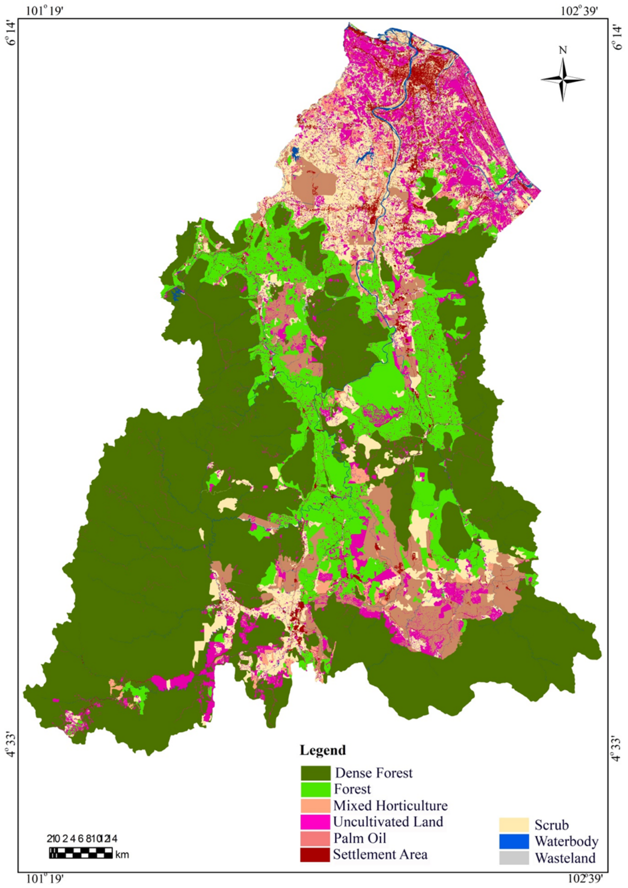

Fig. 3. LULC map of 2015.

Dense Forest: Dense forest was identified by dark red tone and rough textures associated with high relief zones (Fig. 4). The eastern and western part of upstream and midstream are mostly covered with dense forest. It was found that the dense forest at upstream, midstream and downstream are 6067.95 km^2 (73.68 %), 2487.09 km^2 (49.70 %) and 52.59 km^2 (2.81%) respectively in 2005 while it reduces to 5689.31 km^2 (69.09 %), 2068.92 km^2 (41.35 %) and 50.51 km^2 (2.69 %) respectively in 2015. It was found that the reduction of the dense forest was more at midstream (418.17 km^2) than upstream (378.64 km^2) causing a total area reduction of dense forest up to 5.30 %. It converted into plantation activities either palm oil or mixed horticulture, scrub and few kilometres into forest, while at midstream, it changes into forest and palm oil. A few mountain braking activities were also observed at midstream which results increase in wasteland of 2.5 km^2 in ten years. The changes detection results show that all the dense forest is converted into forest, plantation activities and slightly into scrub and wasteland.

Scrub: Scrub was identified by its dark brown and dark red tone, irregular shape and associated with settlement areas, uncultivated land, water body and palm oil plantation in all relief zones (Figs. 5, 6 and 7). The results show that the scrub increases from 333.45 km^2 (4.05 %) at upstream, 544.62 km^2 (10.88 %) at midstream and 562.21 km^2 (29.99 %) in 2005 to 482.18 km^2 (5.86 %) at upstream, 565.54 km^2 (11.30 %) at midstream and 583.18 km^2 (31.11 %) in 2015. From change detection analysis, It was observed that the scrub is mostly changes at upstream may be for plantation activities along the river bank. The changes were also observed near palm oil plantation, settlement areas and uncultivated land. Furthermore, few kilometres increment in scrub at both mid and downstream was observed due to transformation from forest. Total increment of the area is 1.33% in ten years.

Forest: It was identified by dull red tone and smooth textures and associated with moderate relief zones (Fig. 4 and 7). Mostly all the forests are situated in middle of the area and some are at the eastern part of midstream. It was 680.20 km^2 (8.26 %) at upstream, 1020.40 km^2 (20.39 %) at midstream and 46.07 km^2 (2.46 %) at downstream in 2005 while increases to 694.35 km^2 (8.43 %) at upstream, 1414.71 km^2

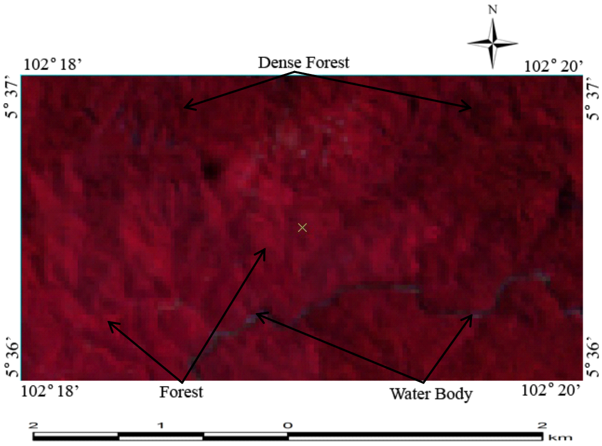

Fig. 4. Dense forest, waterbody and forest are shown in Landsat (30m) image.

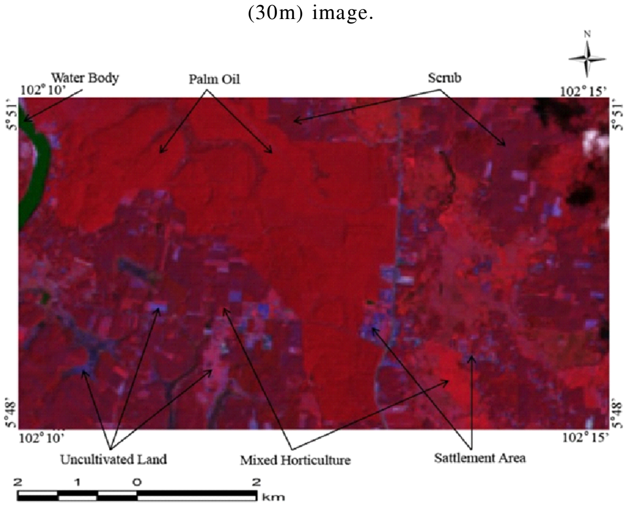

Fig. 5: Water body, palm oil, scrub, uncultivated land, mixed horticulture and settlement area are shown in Landsat (30m) image.

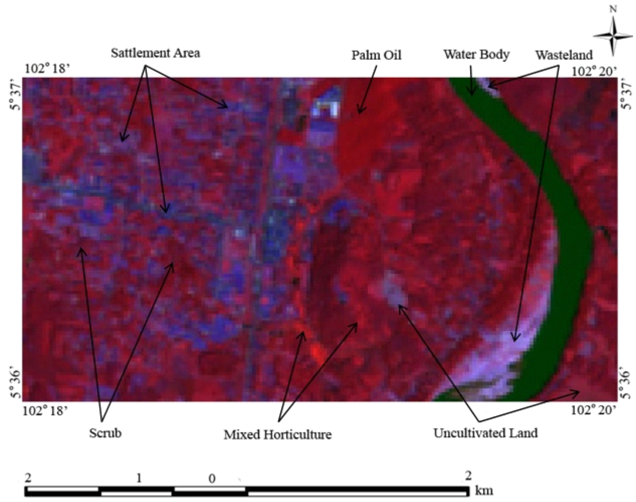

Fig. 6: Water body, palm oil, scrub, uncultivated land, mixed horticulture, settlement area and wasteland are shown in Landsat (30m) image.

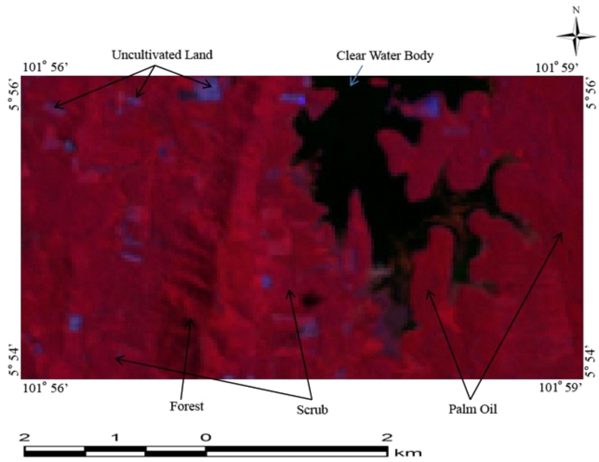

Fig. 7: Water body, palm oil, scrub, uncultivated land and forest are shown in Landsat (30m) image.

(28.27 %) at midstream and 54.43 km^2 (2.90 %) at downstream in 2015. It was observed that the forest increases in each stream but more in midstream due to the transformation of dense forest into forest mostly along the river bank. Total increase in area is 2.75 % in ten years.

Uncultivated land: Uncultivated lands are shown in dark brown tone (saturated) and light pink and blue tone (unsaturated), coarse texture regular or irregular shape and associated with flat areas and deforestation in high, moderate and low relief zones (Fig. 5, 6 and 7). It increases in both upstream (0.57%) and midstream (0.82%) due to deforestation and plantation activities but decreases at downstream (1.06%) due to palm oil plantation. The overall increment of uncultivated land in ten years is 68.33 km^2 (0.45%). The increment at both up and midstream can cause direct contact of rainfall with soil which could result soil erosion and hence transportation of sediments into the rivers. This could lead river overflow at downstream where river depth would be decreased due to deposition of sediments. Thus, this could be one of the main causes of flash flood in the area.

Mixed horticulture: The mixed horticulture was identified by its light red tone, smooth texture, scattered pattern associated with urban areas (Figs. 5 and 6) and it also includes rubber plantation at upstream. It is slightly increased in area of 8.88 km^2 (0.11%) at upstream due to rubber plantation but decreased in both midstream and downstream in area of 235.87 km^2 (4.71%) and 36.35 km^2 (1.94%) respectively due to increase in palm oil plantation followed by slightly increment in settlement area and uncultivated land. Overall, mixed horticulture decrease in area is 263.34 km^2

Table 1: Changes in land use land cover in Kelantan during 2005-2015

Land Use/ Land Cover Categories	Land Use/ Land Cover (2005)								Land Use/ Land Cover (2015)								Difference between 2005 & 2015							
	Upstream		Midstream		Downstream		Total		Upstream		Midstream		Downstream		Total		Upstream		Midstream		Downstream		Total	
	A (km^2)	%	A (km^2)	%	A (km^2)	%	A (km^2)	%	A (km^2)	%	A (km^2)	%	A (km^2)	%	A (km^2)	%	A (km^2)	%	A (km^2)	%	A (km^2)	%	A (km^2)	%
Dense Forest	6067.95	73.68	2487.09	49.70	52.59	2.81	8607.63	56.96	5689.31	69.09	2068.92	41.35	50.51	2.69	7808.74	51.66	378.64	4.60	418.17	8.36	2.08	0.11	798.89	5.30
Forest	680.20	8.26	1020.40	20.39	46.07	2.46	1746.67	11.56	694.35	8.43	1414.71	28.27	54.43	2.90	2163.49	14.31	-14.15	-0.17	-394.31	-7.88	-8.37	-0.45	-416.82	-2.75
Scrub	333.45	4.05	544.62	10.88	562.21	29.99	1440.28	9.52	482.18	5.86	565.54	11.30	583.18	31.11	1630.90	10.85	-148.74	-1.81	-20.92	-0.42	-20.97	-1.12	-190.62	-1.33
Uncultivated Land	423.40	5.14	296.56	5.93	631.14	33.67	1351.10	8.93	470.67	5.72	337.44	6.74	611.32	32.61	1419.43	9.38	-47.28	-0.57	-40.88	-0.82	19.83	1.06	-68.33	-0.45
Palm Oil	519.69	6.31	148.23	2.96	20.17	1.08	688.09	4.54	679.20	8.25	339.52	6.78	42.03	2.24	1060.75	7.01	-159.51	-1.94	-191.29	-3.82	-21.86	-1.17	-372.66	-2.47
Settlement Area	58.17	0.71	114.07	2.28	239.66	12.78	411.90	2.75	58.58	0.71	118.02	2.36	251.12	13.40	427.72	2.79	-0.41	-0.01	-3.95	-0.08	-11.47	-0.61	-15.82	-0.04
Mixed Horticulture	106.02	1.29	330.76	6.61	227.41	12.13	664.19	4.39	114.90	1.40	94.89	1.90	191.06	10.19	400.85	2.65	-8.88	-0.11	235.87	4.71	36.35	1.94	263.34	1.74
Water Body	44.66	0.54	55.21	1.10	74.82	3.99	174.69	1.16	44.66	0.54	55.39	1.11	74.30	3.96	174.35	1.17	0.00	0.00	-0.18	0.00	0.52	0.03	0.34	-0.01
Waste Land	1.47	0.02	7.07	0.14	20.46	1.09	29.00	0.18	1.18	0.01	9.57	0.19	16.57	0.88	27.32	0.18	0.33	0.00	-2.50	-0.05	3.89	0.21	1.68	0.00
Total land	8235.00	100.00	5004.01	100.00	1874.53	100.00	15113.55	100.00	8235.00	100.00	5004.01	100.00	1874.53	100.00	15113.55	100.00								

Table 2: Accuracy assessment details.

		Class type determined from reference sources										
	# Plots	Water Body	Waste Land	Forest	Settlement Area	Scrub	Mixed Horticulture	Palm Oil	Dense Forest	Uncultivated land	Total	User's Accuracy (%)
Class type determined from classified maps	Water Body	98	0	0	0	0	0	0	0	1	99	99
	Waste Land	2	34	0	0	0	0	0	0	1	37	92
	Forest	0	0	97	0	6	0	3	0	3	109	89
	Settlement Area	0	2	0	93		0	0	0	0	95	98
	Scrub	0	1	3	3	81	4	3	0	3	98	83
	Mixed Horticulture	0	0	0	2	6	90	2	0	2	102	88
	Palm oil	0	0	0	0	4	3	92	0	5	104	88
	Dense Forest	0	0	0	0	2		0	100	2	104	96
	Paddy	0	3	0	2	1	3	0	0	83	92	90
	Total	100	40	100	100	100	100	100	100	100	840	
Producer's Accuracy (%)		98	85	97	93	81	90	92	100	83		Total Accuracy 91.4%

(1.74%). This drastic decrease of mixed horticulture at midstream could also be a cause of exposure and detachment of soil which could result soil erosion due to same reason as discussed above.

Palm oil: The palm oil was identified by its red tone, very smooth texture, and particular shape in all streams separated by sharp boundaries with other classes (Figs. 5, 6 and 7). Remarkable increase was found in area of 159.51km^2 (1.94%) and 191.29 km^2 (3.82%) in both upstream and midstream respectively while slight increment in area of 21.86 km^2 (1.17%) is seen at downstream. It was also found that there is cutting of palm oil trees and replantation (observed in both upstream and midstream) which can increase in erosion of sediment and deposition in river due to direct contact with high rainfall.

Settlement area: Settlement areas were characterized by magenta tone with irregular shape and sharp contact with adjacent land use (Figs. 5 and 6). Overall, more increment was observed in area of 11.47 km^2 (0.61%) at downstream along the river bank. It could be a cause of flash flood because of high runoff or river overflow due to decrease in river depth as discussed above and hence loss of human life, agriculture and economy. Furthermore, total increase in area of settlement of 15.82 km^2 (0.04%) was observed.

Water body: It was identified by its black tone (clear water) and dark green tone (water with sediment), smooth texture, sharp boundary outline and irregular pattern (Figs. 4, 5, 6 and 7). Overall, there is no such effect on water body in ten years except few meter extension at midstream due to shifting of rivers may be at that place where two rivers are meeting. Furthermore, few meters shifting were also observed due to sediment deposition at the inner bank in some parts of study area at both mid and downstream.

Wasteland: It exhibits light tone because of high reflectance, irregular pattern with smooth texture, absence of any land use activity or natural vegetation and its association in the study area with water bodies (Fig. 6) and high relief zone where mountain breaking activities is going on. It was 1.47 km^2 (0.02%) at upstream, 7.07 km^2 (0.14%) at midstream and 20.46 km^2 (1.09%) in 2005 while 1.18 km^2 (0.01%) at upstream, 9.57 km^2 (0.19%) at midstream and 16.57 km^2 (0.88%) at downstream in 2015. The only increment of few kilometres was observed at midstream due to anthropogenic activities such as deforestation and mountain breaking. Overall, there is a slight decrease of 1.68 km^2 in area due to increase in uncultivated land and settlement area.

The details of LULC and the changes in all streams under each category are given in Table 1.

Accuracy assessment: The accuracy assessment of this study is very important because of low resolution (30m) satellite data. To find out the accuracy, 100 points of each class except wasteland (40 points due its low spatial extent) were taken randomly on Google Earth and then overlaid on the classified maps. It was found that the overall accuracy of this study was 91.4% (Table 2) with kappa value of 0.990621. Kappa value reflects the difference between actual agreement and the agreement expected by chance. Thus, in this study it shows that there was 99% better agreement than by chance. Results of accuracy assessment is showing that low resolution data can be used in absence of high resolution data but it needs analyst should be expert in finding out spectral reflectance of each class.

SUMMARY

Analysis of each stream (up, mid and down) instead of that of whole catchment shows better results. Variations in up, mid and downstream due to plantation and deforestation expose the soil surface and detaches the particles resulting in the soil erosion during rainfall. However, the amount of erosion depends upon the intensity and duration of the rainfall. The erosion is followed by the transportation of sediments and their deposition where the stream power would reduce (may be at the downstream). The decrease in the river depth thus results in river overflow during or after heavy rainfall at downstream.

In this preliminary flood analysis, the topographic changes affecting the flood in the study area are considered. The class and combination of classes affecting the flood requires more accurate analysis by incorporating hydrological and hydrogeological parameters data as an input for modelling techniques. This can give the detailed insight about the nature and amount of the sediments transported and deposited by rivers and will also provide the qualitative information about the class and combination of parameters contributing to the devastated flood.

CONCLUSION

In this study, spatio-temporal LULC changes (2005-2015) were analyses in Kelantan, Peninsular Malaysia at up, mid and downstream separately. Nine LULC classes such as dense forest, forest, scrub, uncultivated land, mixed horticulture, settlement area, palm oil, water body and wasteland were identified. Major changes was reduction in dense forest in both upstream and midstream, mixed horticulture in mid and downstream due to transformation into forest and palm oil plantation respectively. While increment in forest at midstream and scrub at upstream due to transformation from dense forest, uncultivated land and palm oil plantation activities in both upstream and midstream was observed. These changes clearly indicate that more changes were occurred at upstream and midstream which can cause increase in runoff and land degradation that could result in decrease in river depth and hence river overflows and flash flood at downstream. The accuracy assessment shows that the study was accurate with overall accuracy 91.4 % and kappa value 0.990621. Furthermore, it was found that the use of Landsat data with Google Earth in high resolution data sparse environment is very useful in monitoring spatio-temporal LULC changes.

ACKNOWLEDGEMENT

The authors would like express their appreciation to School of physics and School of Industrial Technology, University Sains Malaysia for providing research facilities to publish this paper. We would also like to acknowledge UniversitiSains Malaysia for providing the financial support through grant 203/PJJAUH/6764002 to carry out this work.

REFERENCES

Al-Bakri, M. Duqqah and Brewer, T. 2013. Application of remote sensing and GIS for modeling and assessment of land use/cover change in Amman/Jordan, Journal of Geographic Information System, 5(5): 509.

Creutin, J. D., Borga, M., Gruntfest, E., Lutoff, C., Zoccatelli, D. and Ruin, I. 2013, A space and time framework for analyzing human anticipation of flash floods. Journal of Hydrology, 482: 14-24.

Eaton, J.M., McGoff, N.M., Byrne, K.A., Leahy, P. and Kiely, G. 2008. Land cover change and soil organic carbon stocks in the Republic of Ireland 1851-2000, Climatic Change, 91(3-4): 317-334.

Ghani, A.A., Zakaria, N. and Falconer, R. 2009. Editorial: River modelling and flood mitigation; Malaysian perspectives, Proceedings of the ICE-Water Management, 162(1): 1-2.

Jin, S. and Sader, S.A. 2005. MODIS time-series imagery for forest disturbance detection and quantification of patch size effects. Remote Sensing of Environment, 99(4): 462-470.

Kibret, K.S., Marohn, C. and Cadisch, G. 2016. Assessment of land use and land cover change in South Central Ethiopia during four decades based on integrated analysis of multi-temporal images and geospatial vector data. Remote Sensing Applications: Society and Environment, 3: 1-19.

Lecce, S.A. 2013. Stream power, channel change, and channel geometry in the Blue River, Wisconsin. Physical Geography, 34(4-5): 293-314.

Pflugmacher, D., Cohen, W.B. and Kennedy, R.E. 2012. Using Landsat-derived disturbance history (1972-2010) to predict current forest structure. Remote Sensing of Environment, 122: 146-165.

Špitalar, M., Gourley, J.J., Lutoff, C., Kirstetter, P.E., Brilly, M. and Carr, N. 2014. Analysis of flash flood parameters and human impacts in the US from 2006 to 2012. Journal of Hydrology, 519: 863-870.

Woodcock, C.E. and Strahler, A.H. 1987. The factor of scale in remote sensing. Remote Sensing of Environment, 21(3): 311-332.

Wulder, M.A., White, J.C., Goward, S.N., Masek, J.G., Irons, J.R., Herold, M., Cohen, W.B., Loveland, T.R. and Woodcock, C.E. 2008. Landsat continuity: Issues and opportunities for land cover monitoring. Remote Sensing of Environment, 112(3): 955-969.

Zhang, C., Cooper, H., Selch, D., Meng, X., Qiu, F., Myint, S.W., Roberts, C. and Xie, Z. 2014. Mapping urban land cover types using object-based multiple endmember spectral mixture analysis. Remote Sensing Letters, 5(6): 521-529.

Zhu, Z. and Woodcock, C.E. 2014. Continuous change detection and classification of land cover using all available Landsat data. Remote Sensing of Environment, 144: 152-171.