Land use change and soil loss risk assessment by using geographical information system (GIS): A case study of lower part of Perak River

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Abstract. The developing mode of the nation enhance more land area being exploited to generate economy income. Objectives of this study were to analyse the land use changes from year 2010 to 2013 and soil erosion potential rate for year 2013 of lower part of Perak river basin. All of the spatial analysis work were carried out in the GIS environment using the ArcGIS version 9.3 software. Land use maps were obtained from Department of Agriculture and been digitized accordingly. The total area was 2914.91 km$^2$ and land use categories were clustered into various classes. Based on land use change analysis, oil palm plantation recorded some increment from year 2010 to 2013. While area of forest depleting from 95.54 km$^2$ to 86.01 km$^2$ indicating that the forest area were being exploited and shifted to other land use type. In the other hand, the rubber plantation decrease due to land conversion into palm oil plantation. Urban area showed some increment in coverage proving the current blooming number of population occurs rapidly. In context of cleared land, 2013 recorded higher coverage of cleared land compared to the year 2010 which recorded a shifting from 8.89 km$^2$ in 2010 to 21.24 km$^2$ in 2013. By adopting the RUSLE model, in 2013, the soil erosion potential was categorised as very low (0-1 tons/ha/year) with some soil erosion hotspot spotted within the study area. The soil erosion range from very low to extreme class. A very low soil erosion potential class (0-1 ton/ha/yr) recorded the majority of 61% (1765.60 km$^2$) of total area. The extreme classes (>100 ton/ha/yr) recorded about 18% (536.19 km$^2$) of the total area. According to the result, it can be concluded that the middle part of study area experience low to severe classes of potential soil erosion.

1. Introduction

Recently, the over-utilization of land use rises because of the demand from rapidly increasing number of population and plantation along the river basin. These factors speed up the occurrence of soil erosion along the river which indirectly will contribute toward water quality status declining and alteration of river hydro-morphology.

Land use activity such as agriculture sectors overly speed up the soil erosion process and lead to the deteriorating of the river water quality resulted from the high transportation of the suspended sediment loads [1]. This is due to the transported sediment from the surrounding activities along the river will be deposited at the bottom of the river. River system degradation is expected to alter the river morphology as the river bank and depth of the river will be affected [2]. Consequently, suitability of a habitat for the various biodiversity will decrease because of the river bottom becoming shallower [3]. For instance, many previous research had proven that land use change can deteriorate...
many environmental aspects such as environmental services [4], carbon and nitrogen sequestrations [5], water yield [6], carbon stocks [7] and aquatic life [8]. As soil erosion becoming a severe environmental threat mainly towards the river water conservation, the risk assessment of soil erosion triggered by water is important in designing new and effective water and soil management policies [9].

Thus, aims of this study are to investigate the land use changes pattern, soil erosion risk analysis and its potential impact towards the river ecosystems in Perak River, by adopting geospatial analysis in GIS environment. The river ecosystem will reflects the health of the river and its suitability for the biotic components such as fish, terrapins, and others. The sequence of land use maps and soil maps were sourced from the Department of Agriculture and been digitized to determine the land use change percentage and soil loss risk categories.

2. Methodology

2.1 Study area

The study was carried out in the lower part of Perak River basin located at the north of Peninsular Malaysia. The study area is located at the Perak River which is the second longest river in Peninsular Malaysia after the Pahang River. It covered 70% of the state land and flows over 400km in 15,000 km². Various activities carried out along the Perak River such as sand mining, development of residential area, industrial area, plantation, aquaculture and others.

Figure 1. Study area.
In terms of ecosystem conservation, Perak River is an important habitat for endangered species of river terrapin or *Batagur affinis*. This top 25 most threaten turtle species also has been listed as a critically endangered species according to International Union for Conservation of Nature (IUCN) Red List 2009 and Convention of International Trade of Endangered Species of Wildlife Flora and Fauna (CITES) Appendix 1. In conjunction of that, Bota Kanan Tuntung Centre, the conservation centre for terrapin was established by the Perak Wildlife and National Parks Department in 1967 to nurture the sustainability of river terrapin population in Perak River. Thus, it is vital to ensure the health of this river must be the concern of many not only to preserve the precious endangered species of river terrapin, but also to sustain other aquatic organism and any environment services that Perak River would offer.

2.2 ArcGis 9.3

By using the ArcGIS version 9.3, the land use change and soil loss risk analysis were conducted based on the 2010 and 2013 land use maps and soil map of current years. The digitizing process included the soil reconnaissance map and the land use map for each of the year of 2010 and 2013.

2.3 Dataset

Primary data used in this research were the coordinate obtained from ground truthing activity. Secondary dataset employed in this research were reconnaissance soil map and land use maps of Perak River of year 2010 and 2013. The map was published by the Management and Conservation of Land Resources, Department of Agriculture Malaysia (DOAM).

2.3.1 Data acquisition

There are primary and secondary data involve in the study.

2.3.2 Primary data

Site verification is performed to compare the real observation with the output which represent by the map [10]. Site verification is by determined the coordinates using GPS and observed the current situation at the study area. Observation at the study area are proved by captured some pictures.

2.3.3 Secondary data

The topography map sourced from Department of Survey and Mapping Malaysia (JUPEM) was used as the references of study area. The land use maps of 2010 and 2013 were sourced from Department of Agriculture (DOAM). Land use maps were provided in the image format (.jpeg) of 1:300 000 in scale. The rainfall data was obtained from the Department of Irrigation (DID). The rainfall data of year 2010 and 2013 are obtained to determine the annual rainfall of the study area.

3. Results & discussion

3.1 Land use

The land use map of Perak lower part river basin from year of 2010 and 2013 have been used as it required to perform the land use change analysis from year 2010 to 2013 which encompasses the total area of 2914.91 km².
Table 1. Land use type of Perak River lower part basin. The type of land use has been categorised into ten different types.

| No | Land Use Type           | Area (km²) | 2010 | 2013 |
|----|-------------------------|------------|------|------|
| 1  | Others Plantation/Crops | 311.15     | 261.19 |
| 2  | Cleared Land            | 8.89       | 21.24 |
| 3  | Forest                  | 95.54      | 86.01 |
| 4  | Oil Palm                | 2061.34    | 2115.74 |
| 5  | Mining Area             | 18.45      | 16.44 |
| 6  | Paddy Field             | 228.21     | 232.7 |
| 7  | Others Economic Activities | 9.67   | 9.9 |
| 8  | Rubber                  | 78.18      | 77.1 |
| 9  | Urban Area              | 52.25      | 59.6 |
| 10 | Water Bodies            | 51.24      | 34.99 |
|    | TOTAL                   | 2914.91    | 2914.91 |

3.1.1 Land use change of 2010

Based on land use map of year 2010 (Figure 2.) and land use area (Table 1.), the dominant land use in study area was oil palm plantation covering about 70.72 % (2061.34km²) of the study area. The second highest of land use area was Other Plantation/Crops which cover about 10.67% (311.15km²). The third highest reading was the paddy field which contribute about 7.83% (228.21km²). Forest only cover about 3.28% (95.54km²) of the total area. The other land use type were rubber plantation and urban area which contribute about 2.68% (78.18 km²) and 1.79% (52.25km²) respectively.
3.1.2 Land use change of 2013

Based on the Figure 3, the land use of year 2013 shows that the oil palm plantation recorded the highest percentage of land use type covering an area of 72.58% (2115.74 km²). The second highest was the others plantation/crops which recorded for about 8.96% (261.19 km²). These classes of land use represent the mixed horticulture, scrubs and others plantation or crop except the oil palm, paddy and rubber plantation. Some of the area within the study area had been converted to the others plantation/crops land use class. The paddy field is the third highest of the land use type which is 7.98% (232.7 km²). The others land use type or class such as rubber plantation, urban area, forests, water bodies, cleared land, other economic activities and mining area donated approximately about 10% to the total study area. The 2013 land use map of 2013 sourced from DOA represent the most recent land use status in lower part of Perak river basin.

3.2 Land use change

Based on the Figure 3, the land use of year 2013 shows that the oil palm plantation recorded the highest percentage of land use type covering an area of 72.58% (2115.74 km²). The second highest was the others plantation/crops which recorded for about 8.96% (261.19 km²). These classes of land use represent the mixed horticulture, scrubs and others plantation or crop except the oil palm, paddy and rubber plantation. Some of the area within the study area had been converted to the others plantation/crops land use class. The paddy field is the third highest of the land use type which is 7.98% (232.7 km²). The others land use type or class such as rubber plantation, urban area, forests, water bodies, cleared land, other economic activities and mining area donated approximately about 10% to the total study area. The 2013 land use map of 2013 sourced from DOA represent the most recent land use status in lower part of Perak river basin.
Table 2. Area of land use change. Depending to various factor, land use classes can be shifted from one to another land use classes.

| No. | Land Use Change                               | Area (km$^2$) |
|-----|-----------------------------------------------|---------------|
| 1   | Urban Area                                    | 50.56         |
| 2   | Other Economic Activities                     | 10.41         |
| 3   | Cleared Land                                  | 6.21          |
| 4   | Others Plantation/Crops                       | 260.47        |
| 5   | Others Plantation/Crops to Urban Area         | 8.57          |
| 6   | Others Plantation/Crops to Paddy Field        | 3.60          |
| 7   | Forest to Cleared Land                        | 6.79          |
| 8   | Water Bodies                                  | 31.89         |
| 9   | Mining Area to Mining Area                   | 19.89         |
| 10  | Oil Palm to Urban Area                        | 14.09         |
| 11  | Oil Palm to Others Plantation/Crops           | 22.74         |
| 12  | Oil Palm                                      | 2008.54       |
| 13  | Oil Palm to Paddy Field                      | 6.25          |
| 14  | Others Plantation/Crops to Oil Palm           | 24.91         |
| 15  | Paddy Field                                   | 223.71        |
| 16  | Rubber to Oil Palm                            | 43.61         |
| 17  | Rubber                                        | 63.34         |
| 18  | Forest                                        | 89.50         |
| 19  | Oil Palm to Rubber                            | 6.71          |
| 20  | Water Bodies to Oil Palm                      | 13.04         |

Figure 5. Land use change type against area of land use change.
The above figure shows the land use change from year 2010 to 2013. Depending on various factors, land use classes can be shifted from one to another land use classes (Table 2). The overall land use change from 2010 to 2013 as displayed in Figure 4. Based on result, oil palm plantation recorded some increment from year 2010 to 2013. While, area of forest depleting from 95.54 km$^2$ to 86.01 km$^2$ indicating that the forest area were being exploited and shifted to other land use type. In the other hand, the rubber plantation decrease due to land conversion into palm oil plantation. Urban area showed some increment in coverage proving the current blooming number of population occurs rapidly. In context of cleared land, 2013 recorded higher coverage of cleared land compared to the year 2010 which recorded a shifting from 8.89 km$^2$ in 2010 to 21.24 km$^2$ in 2013. The others land use also undergoes changes from year of 2010 to 2013.

3.3 Soil erosion analysis

The soil erosion analysis is performed to determine the hotspot of soil erosion in study area. There are four factors that considered during performed the soil erosion analysis such as soil type, management practices, crop system, annual rainfall and elevation [11].

Models such as USLE [12] and its revised version RUSLE [13] are widely used method used for estimating the annually soil erosion potential rate as this method employ lesser field data instead of any other more complex data input [14]. The RUSLE model was employed in this research in order to perform the soil erosion analysis.

The RUSLE model are as below:

$$A = LS \times R \times K \times C \times P$$

where
- $A$ = Annual Soil Erosion Rate, ton/ha/yr
- $R$ = Annual rainfall erosivity factor, MJmm/ha/h/yr
- $K$ = Soil erosivity factor Mg h/MJ/mm
- $LS$ = Slope length and steepness factor
- $C$ = Cover management factor
- $P$ = Conservation practice factor

3.3.1 Soil type

![Soil Type Map Of Lower Part Perak River Basin](image)

Figure 6. K-Value map of lower part of Perak River basin.
The soil type within the study area are determined according to the soil reconnaissance map sourced from the DOA. A variety of soil type are found in the study area. The soil type found in the study area are briah-organic clay and muck, holyrood-lunas, peat, mined land, rengam-kala, sogomana-setiawan-manik, rudua–rusila, Selangor, kangkung, organic clay and muck, kranji, rengan-bukit temiang, serdang-bungor-muncung, steeland, telemung-akob-local alluvium and urban land. The k-value factor were analysed according to the value obtained from Department of Agriculture.

3.3.2 P-factor map

![Figure 7. The P-Value map of lower Part Perak River basin.](image)

From the map above (Figure 7), the P factor value are in the range of 0.2 to 1.0. The lower the P value, the more effective of adopted conservation practice to reduce the soil erosion. According [15], P value reflects the amount of erosion happened when any practice is employed compared to what would occur without that particular practice.

3.3.3 C-factor map

![Figure 8. The C-Value map of lower part Perak River basin.](image)
Figure 8 shows the Cover Management Factor of the study area. This factor are determine by referring to the land use type within the study area. It indicates the effect of conservation plan towards the annual soil erosion potential rate [16]. The cover management factor is referring to the ratio of soil erosion with the vegetation cover over that land use type. The vegetation cover is different for the land use type where the protected land have higher C value compared to bare land. The C value were sourced from Department of Agriculture.

3.3.4 R-factor map

![R-Value map of lower part Perak River basin.](image)

The annual rainfall factor is referring to the erosion potential of the study area related to the rainfall intensity and the potential rain ability to create the erosion. For this study, the annual rainfall capacity recorded for the year 2013 was 2314 mm (Figure 9). This will represent the total annual rainfall capacity for the study area. The rainfall data is obtained from Department of Irrigation and Drainage.
3.3.5 Slope factor map

Figure 10. Slope map of lower part Perak River basin.

LS factor derivation was obtained from the Survey and Mapping Department (JUPEM). Figure 12 shows the slope map of the study area. Dominantly, the study area have the slope rate range from 0.00 to 0.09. Higher slope area was observed at the south part of study area. The highest elevation found in the study area is about 600 m from the mean sea level. However, majority of the area lies under 100 m from the mean sea level.

3.3.6 Soil erosion map

Figure 11. Soil erosion potential map of lower part Perak River basin.
Figure 12. Soil erosion potential hotspot (circle) map of lower part Perak River basin.

Table 3. Soil erosion potential. Erosion potentials are categorised into 6 different classes.

| Erosion Class | Erosion Rate (ton/ha/yr) | Soil Erosion Potential | Area (km²) |
|---------------|--------------------------|-------------------------|------------|
| 1             | 0-1                      | Very Low                | 1765.60    |
| 2             | 1-5                      | Low                     | 94.61      |
| 3             | 5-10                     | Moderate                | 102.53     |
| 4             | 10-20                    | High                    | 160.05     |
| 5             | 20-50                    | Severe                  | 255.03     |
| 6             | >100                     | Extreme                 | 536.19     |
|               |                          | TOTAL                   | 2914.00    |

Figure 12 and Table 3 shows the soil erosion potential within the study area. The soil erosion range from very low to extreme class. The soil erosion potential for very low (0-1 ton/ha/yr) classes recorded the majority of 61% (1765.60 km²) of total area. The extreme classes (>100 ton/ha/yr) recorded about 18% (536.19 km²) of the total area. It can be concluded that the middle part of study area experienced low to severe classes of potential soil erosion.

4. Conclusion

According to the study, the land use in lower part of Perak river basin was dominantly been covered by oil palm plantation for both year of 2010 and 2013. In addition of that, most of the study area were exploited and converted from forest area to agriculture sector especially into oil palm and rubber plantation. The forest area in the study area decreases from 2010 to 2013. The soil erosion range from very low to extreme class. The soil erosion potential for very low (0-1 ton/ha/yr) classes recorded the majority of 61% (1765.60 km²) of total area. The extreme classes (>100 ton/ha/yr) recorded about 18% (536.19 km²) of the total area. It can be conclude that the middle part of study area suffer low to severe classes of potential soil erosion.
References

[1] Ahearn, D. S., Sheibley, R. W., Dahlgren, R. a., Anderson, M., Johnson, J., & Tate, K. W. (2005). Land use and land cover influence on water quality in the last free-flowing river draining the western Sierra Nevada, California. Journal of Hydrology, 313(3-4), 234–247. http://doi.org/10.1016/j.jhydrol.2005.02.038

[2] Allan, J. D. (2004). Landscapes and Riverscapes: The Influence of Land Use on Stream Ecosystems. Annual Review of Ecology, Evolution, and Systematics, 35(1), 257–284. http://doi.org/10.1146/annurev.ecolsys.35.120202.110122

[3] Aiken, R.R., & Leigh, C.H. (1985). On the Declining Fauna of Peninsular Malaysia in the Post Colonial Period. Ambio, (1491), 15-22.

[4] Gao, J., Li, F., Gao, H., Zhou, C., & Zhang, X. (2016). The impact of land-use change on water-related ecosystem services: a study of the Guishui River Basin, Beijing, China. Journal of Cleaner Production, 1–8. http://doi.org/10.1016/j.jclepro.2016.01.049

[5] Deng, L., Wang, G., Liu, G., & Shangguan, Z. (2016). Effects of age and land-use changes on soil carbon and nitrogen sequestrations following cropland abandonment on the Loess Plateau, China. Ecological Engineering, 90, 105–112. http://doi.org/10.1016/j.ecoleng.2016.01.086

[6] Jia, X., Fu, B., Feng, X., Hou, G., Liu, Y., & Wang, X. (2014). The tradeoff and synergy between ecosystem services in the Grain-for-Green areas in Northern Shaanxi, China. Ecological Indicators, 43, 103–111. http://doi.org/10.1016/j.ecolind.2014.02.028

[7] Tao, Y., Li, F., Wang, R., & Zhao, D. (2015). Effects of land use and cover change on terrestrial carbon stocks in urbanized areas: A study from Changzhou, China. Journal of Cleaner Production, 103, 651–657. http://doi.org/10.1016/j.jclepro.2014.07.055

[8] Elosegi, A., Díez, J., & Mutz, M. (2010). Effects of hydromorphological integrity on biodiversity and functioning of river ecosystems. Hydrobiologia, 657(1), 199–215. http://doi.org/10.1007/s10750-009-0083-4

[9] Xu, L., Xu, X., & Meng, X. (2013). Risk assessment of soil erosion in different rainfall scenarios by RUSLE model coupled with Information Diffusion Model: A case study of Bohai Rim, China. Catena, 100, 74–82. http://doi.org/10.1016/j.catena.2012.08.012

[10] Dawn C. Parker, Steven M. Manson, Marco A. Janssen, Matthew J. Hoffmann & Peter Deadman (2003) Multi-Agent Systems for the Simulation of Land-Use and Land-Cover Change: A Review, Annals of the Association of American Geographers, 93:2, 314-337, DOI: 10.1111/1467-8306.9302004

[11] Stone, R. P., & Ontario. Ministry of Agriculture, Food and Rural Affairs. (2000). Universal Soil Loss Equation, USLE. Ministry of Agriculture, Food and Rural Affairs.

[12] Wischmeier, W.H., Smith, D.D., 1978. Predicting rainfall-erosion losses — aguide to conservation planning. Agriculture Handbook. N°537. USDA Forest Service, Washington, D.C.

[13] Renard, K.G., Foster, G.R., Weesies, G.A., Mc Cool, D.K., Yoder, D.C., 1997. Predicting Soil Erosion by Water: a Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). Agriculture Handbook N° 703. Natural Resources Conser- vation Service.Washington DC, USDA.

[14] Fernández, C., & Vega, J. A. (2016). Geoderma Evaluation of RUSLE and PESERA models for predicting soil erosion losses in the fi rst year after wild fi re in NW Spain. Geoderma, 273, 64–72. http://doi.org/10.1016/j.geoderma.2016.03.016

[15] Treh, Frederick R & Hobbs, J. Arthur (James Arthur), 1914-& Donahue, Roy Luther, 1908- (1999). Soil and water conservation : productivity and environmental protection (3rd ed). Prentice Hall, Upper Saddle River, NJ

[16] Ramli, M. F., Mei, C. S., Yusoff, M. K., & Makmom, A. (2004). Preliminary Assessment of Erosion Hazard using Open Source, (September), 12–14.