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Original Article

Analysis of satellite remote sensing and driver-pressure-state-impact-response framework in Selangor river basin area

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Abstract

Forest resources have come under growing pressure over time that led to forest degradation. The goal of this research is to use remote sensing to examine land cover changes in the study region, and then to construct the DPSIR framework for future decision making. Datasets of four Landsat images were based upon to produce the land-cover map and identify the land-cover changes. The Landsat images' methodology of land-cover classification was unsupervised pixel-based classification. The specific land cover includes forest, built-up area, bare land, vegetation, water bodies, and cloud. Image classification found that forest changed between 1990 and 2020 were decreasing, respectively, at 17.05 percent of total change. An increase was noted in the built-up area, by 18.56 percent over the 30-year timeline. Factors contributing to the decrease of forest include anthropogenic factor. A DPSIR framework was produced to provide the relevant indicators and allow policymakers to contribute input on environmental concerns of the future impact in policy development.

Keywords: land cover, forest, Selangor River basin, remote sensing

1. Introduction

There are three types of forestry decisions that can be made remotely: spatial planning, land cover mapping, and biomass estimation. For spatial planning, the objective is usually to compute the optimal distribution of resources (e.g., fire prevention zones or target harvest areas). Adaptive strategy development and strategic spatial planning approaches able to ensure appropriate integration of forests and their management are properly integrated into rural development at the local, landscape, and regional levels (Uibrig, & Hilbrich, 2014).

Remote sensing measures forest structure and composition at a regional rather than individual tree scale. In forest study, land cover mapping is estimating what lands are forested and which areas should be included in an inventory. Inventory analysis includes measurement of tree cover (Jin, Oh, Shin, Njungwi, Choi, 2020; Korhonen, Korhonen, Rautiainen, Stenberg, 2006) tree cover fraction (Duhl, Guenther, Helmig, 2012; Liang, & Wang, 2020) and detection of the distribution of tree species (Du, Hu, Zeng, Wang, Peng, Zhang *et al.*, 2017; Serra-Diaz, Enquist, Maitner, Merow, Svenning, 2018). Remote sensing can be used to map vegetation in a country or regional scale. Remote sensing techniques and land cover mapping are commonly used in the

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determination of sustainable forest management and in defining areas that can be suited for conservation and restoration.

The use of remote sensing can provide information of the land cover mapping at spatial and temporal scales and able to revisit the area as data archives are available. The coarse and medium satellite imagery datasets include Landsat and Satellite pour l'Observation de la Terre (SPOT) for forest changes analysis (Shimizu, Ota, & Mizoue, 2019). A very high resolution (VHR) imagery can also be used for forest mapping (Schepaschenko, See, Lesiv, Bastin, Mollicone, *et al.*, 2019) and hyperspectral data using spectroradiometer have been used to detect the most valuable spectral regions, in this case for forest changes (Mohd Hasmadi, & Kamaruzaman, 2008; Shin, 2015). Some of the forest studies using multi-resolution optical, light detection and ranging (LiDAR) data and synthetic aperture radar (SAR) for forest degradation (Mitchell, Rosenqvist, Mora, 2017).

A land-cover-changes analysis in Ghana and India are found that the land-cover between 1985 and 2006 were the result of multiple anthropogenic and climatic activities (Forkuo, & Frimpong, 2012; Roy, & Arijit, 2010). Aburas, Abdullah, Ramli, and Ash'aari (2015) and Asnawi, Ahmad, Choy, Syahir, and Khair (2018) found that the factors such as rapid urbanization, population increase and deforestation have affected their original land function.

However, in Kelantan simulated land cover in 2025 shows that the built-up area is anticipated to grow in major cities in central and southern Kelantan, signaling the beginning of a sprawl growth (Mahamud, Samat, Tan, Chan, & Tew, 2019). These studies mentioned are essential for monitoring the urban sprawl that has impacted the local natural resources and the management of forest areas. On the other hand, the forest area in Penang Island was found to decline by 26 percent between 1991 and 2009, while the urban and grassland areas rose by 21 percent and 71 percent, respectively (Tan, Lim, & Jafri, 2011).

Apart from that, a study in Gombak, Selangor has discovered a 15.5 percent decline in forest cover between 1989 and 2014 (Asnawi, & Kuok, 2016). In addition, Aisyah, Shahrul, Zulfahmie, Sharifah Mastura, & Mokhtar (2015) found that agricultural development and rapid urbanization were the major causes of decrease in forest and natural resources land cover in Selangor for about 16,420 hectares from 1989 to 2011, which is expected as the population grows and the market for new residential neighborhoods expands.

To understand the future action in environmental study, the driver-pressure-state-impact-response (DPSIR) framework is able to provide the indicators needed to provide feedback to policymakers on environmental quality (Kristensen, 2004). In addition, the integration of remote sensing with the DPSIR framework develops an explanatory framework for a better understanding of the drivers, impacts, and responses to unfavorable land cover changes in a specific location (Mansur, Hasmadi, Azani, & Alias, 2017).

Kyere-Boateng, & Marek (2021) used DPSIR to show the chain of causal links that lead to deforestation in Ghana. A study in urban areas Liu, Ding, Xue, Zhu, and Gao (2020) used the DPSIR framework to show that due to the rapid upward trend of urban socio-economic and population development. Other environmental study used the DPSIR framework shows that mangroves have been declining in Johor over the last several decades, with population trends as the primary cause and development for urban or agricultural purposes indicated as land use pressures (Sarmin, Hasmadi, Pakhriazad, & Khairil, 2016). These studies show that DPSIR provides a connection between human activities and associated pressures, resulting in ecological changes and decision-makers taking action.

The forests of Malaysia are managed under the Forestry Department Peninsular Malaysia, at the federal level are responsible for the management, planning and protect the Permanent Reserved Forest (PRF). The two key forest policies in Malaysia are *The National Forestry Act of 1984* and the *National Forestry Policy of 1978*. These regulations are designed to protect forest management zones from any prohibited activities. Each state has the authority to establish forestry legislation and create forestry policy on its own. Only technical advice and support from the federal government is provided in the areas of forest management, training, research, and the upkeep of experimental and demonstration stations (Mokthsim, & Salleh, 2014). Nonetheless, when it comes to all land and forestry problems, strong cooperation between the states and the federal government is critical.

Those critical decisions are to balance the needs of environmental care and economic management. According to the Selangor State Assembly, based on the sustainable forest management (SFM) principle, no logging license has been issued by the Selangor State Forestry Department until today, in line with the 25-year moratorium policy for logging currently practiced by the Selangor State Government on logging activities in the permanent forest reserves (PFR). The objective of the moratorium policy is to ensure that PFR are conserved, and the habitat and ecosystem are sustainable.

Therefore, the present study intends to analyze the pattern of land-cover changes in the Selangor River Basin for three decades, i.e. from 1990 to 2020, using remote sensing and GIS technology. The study will also develop a DPSIR framework and analyze the land cover changes in the Selangor River Basin area.

2. Study Area

The Selangor River Basin (Figure 1) acts as a water catchment area. The area is about 2,200 km^2 or 28 percent of the state [Lembaga Urus Air Selangor (LUAS)]. The Selangor River Basin starts from the foothills of Fraser's Hill and runs for 110 km through Selangor's north-east area until it reaches the shore (Kusin, Muhammad, Md Zahar, Madzin, 2016). For this study area, the Selangor basin covers a part of three districts: Gombak, Hulu Selangor, and Kuala Selangor, which are under the administration of three local authorities: Selayang Municipal Council, Kuala Selangor District Council, and Hulu Selangor District Council.

The study area is located in the northern part of the state of Selangor. The study area has a tropical climate with hot and humid, an average mean maximum temperature of 22.8 °C to 33.4 °C. Elevations in the study area varies from 300 and 570 meters above sea level. The study area is characterized by two monsoon seasons: the northeast monsoon season and the southwest monsoon season. The former occurs from November to March, while the latter occurs from May to September. The mean monthly rainfall varies from 80 mm to 242 mm. The rainfall and temperature

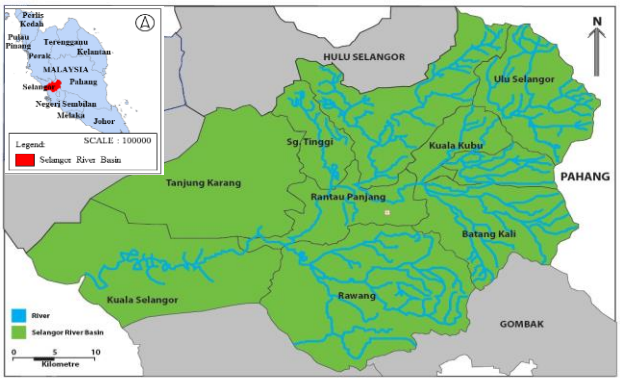

Figure 1. The Selangor river basin area

patterns during the dry season have affected the sediment pattern upstream of the Selangor River Basin, while land-use changes influenced the sediment pattern downstream (Nurhidayu, Faizalhakim, & Shafuan, 2016).

3. Methodology

The land cover detection analysis was the essential aspect of this study. Remote sensing and the GIS approach were applied to detect changes in land cover by analyzing four Landsat images in 1990, 2000, 2010, and 2020. The methodology of this study consisted of five main stages: acquisition data, data pre-processing, image classification, accuracy assessment, and final product. These stages are illustrated in Figure 2.

3.1 Metadata

Table 1 shows in detail the metadata of the four images that were analyzed using the unsupervised method. The metadata shows that among the images is the minimum percentage for cloud interference.

3.2 Data Acquisition

The secondary data used in this study was four satellite images obtained from the open platform of the United States Geological Survey (USGS). The data for the years 1990, 2000, 2010, and 2020 were obtained from the Landsat satellite. This study took the dates based on the quality of the images throughout the study year.

3.3 Data pre-processing

Landsat imagery pre-processing and unsupervised classification methods were performed in this study (Lillesand, Kiefer, & Chipman, 2015). Images were classified into five land cover classes; forest, bare land, built-up area, water body, and cloud.

3.4 Accuracy assessment

The accuracy assessment reflects the real difference between our classification and the reference map or data (Lillesand *et al.*, 2015). The accuracy assessment compares the classified image to topographic map. The reference data used for the 1990 image was a topography map of Kuala Selangor that was produced in 1984. For the 2010 image, the reference data was the topography map produced in 2010, and for the 2020 image, the data reference used was that obtained from recent image of Google Map. It considered to be accurate data to understand better-classified image interpretation (Asnawi, Ahmad, Choy, Syahir, Khair, 2018).

Producer's accuracy measures errors of omission, which is a measure of how well real-world land cover types can be classified. User's accuracy measures errors of commission, which represents the likelihood of a classified pixel matching the land cover type of its corresponding real-world location (Congalton, 1991). The kappa coefficient and error matrix have become common methods for evaluation of image classification accuracy.

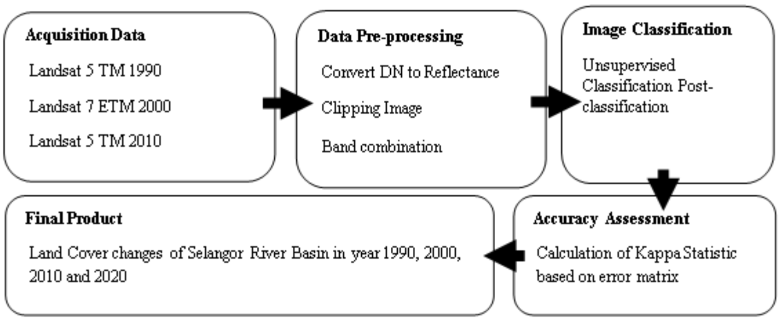

Figure 2. Method of land cover changes using remote sensing

Table 1. Metadata of land satellite images at Selangor river basin

Year	Date Acquired	WRS Path	WRS Row	Start Time	Stop Time	Cloud (%)
1990	1990/03/06	127	058	02:49:13	02:49:40	4
2000	2000/02/06	127	058	03:21:07	03:21:34	8
2010	2010/02/09	127	058	03:19:15	03:19:42	6
2020	2020/02/05	127	058	03:28:23	03:28:55	12

All the images were verified using an available topography map and Google Maps. A set of random points were generated on the classified images and then tabulated as an error matrix to perform the accuracy calculation. The year 2020 map was recorded with the highest accuracy (93 percent), followed by the year 2000 map (92 percent), the year 2010 map (91 percent), and the year 1990 map (90 percent). Table 2 provides the breakdown of the data.

Table 2. Accuracy assessment using matrix error for 1990, 2000, 2010 and 2020

Class name	Producer's accuracy (%)	User's accuracy (%)
Landsat 5 TM 1990		
Water bodies	75	72
Bare land	98	95
Forest	100	100
Built-up area	95	92
Vegetation	92	90
Average accuracy	92	90
Landsat 7 ETM 2000		
Water bodies	90	80
Bare land	95	93
Forest	98	95
Built-up area	84	84
Vegetation	90	100
Average accuracy	91	90
Landsat 5 TM 2010		
Water bodies	85	85
Bare land	84	81
Forest	90	88
Built-up area	96	96
Vegetation	100	100
Average accuracy	91	90
Landsat 8 OLI-TIRS 2020		
Water bodies	80	78
Bare land	100	96
Forest	98	98
Built-up area	100	100
Vegetation	98	96
Average accuracy	95	94

3.5 DPSIR framework development

The development of a DPSIR framework is according to inputs from and relationships from the land cover changes retrieved from this research. First, this study examines factors to the driving force that influence the results of land cover changes analysis. At the same time, the effect on driving force in the pressure that will occur on land cover changes. Next, the stress has affected the current situation or state of the study area. The study also considers whether the current situation will impact development sectors such as physical, economic, social or environmental. Finally, an estimation of the appropriate response taken by the parties involved through relevant measures. Several experts have reviewed and confirmed DPSIR provided in this research.

4. Results and Discussion

Figure 3 shows the graph of land cover changes of Selangor river basin area. The unsupervised classification of Landsat images for the years 1990, 2000, 2010, and 2020

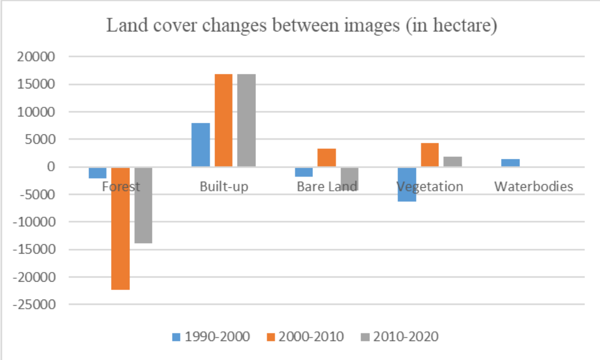

Figure 3. Graph of the land cover changes (by hectare) according to period (1990-2000), (2000-2010) and (2010-2020)

(Figure 4) shows that the forest area consistently shrinking until 2020. On the other hand, the built-up area has consistently increased since 1990 to 2020. A small varies can be seen from the land cover changes between vegetation, bare land and water bodies. Vegetation also represented agricultural area, including paddy fields and palm oil.

In 1990, the highest forest coverage 108,546.9 ha^2 (48 percent) and lowest are built-up area 1407.51 ha^2 (1 percent). In 2010, the forest coverage was slightly lower than previously 106,434.4 ha^2 (47 percent) and continuously to decrease in 2010 to 84,174.03 ha^2 (37 percent). During 2000 to 2010, logging and land clearing activities also took place during the period, only in 2007, some parts of the forest were gazetted as State Parks in 2007 (Dewan Negeri Selangor [DUN], 2010).

There is a decrease in forest between 2010 and 2020 (70,239.33 ha^2), however, the decrease rate was slower of 6 percent compared to the 10 percent of the previous decade (2000-2010). The improvement could be due to the 25-year moratorium policy prohibiting any logging activity in Selangor. The reduction of the forest was also due to the conversion of oil-palm plantations to cropland, which has brought about unlimited economic profits (Alam, & Begum, 2015).

The built-up area shows a consistent growth for three decades of year study. There was only 1 percent (1407.51 ha^2) of built-up area in 1990 and increased to 4 percent (9380.43 ha^2) after a decade (2000). In the 2000 map, it was noted that the Selangor dam was constructed at the north-eastern of the study area. In 2010, the Selangor dam was successfully built in 2010 map (Figure 4). It can be seen some forest change in areas where roads had expanded into forested areas.

A drastic growth of built-up area from 26210.61 ha^2 in 2010 (11.67 percent) to 42,128.27 ha^2 in 2020 (19.19 percent). This was observed increased urbanization due to demographic drivers (i.e., human population growth), such as development multiple residential areas. Land conversion of the plantations was also observed (Nurhidayu *et al.*, 2016).

A steady pattern of vegetation can be seen in Figure 3. A decrease of vegetation from 96,125.67 ha^2 in 1990 (43 percent) to 89,868.96 ha^2 in 2000 (40 percent) are due to the conversion to urban area. Then, a slight increase to 94,151.97 ha^2 (42 percent) and 95,994.27 ha^2 (43 percent) in 2010 and 2020, respectively. This scenario happened due to the

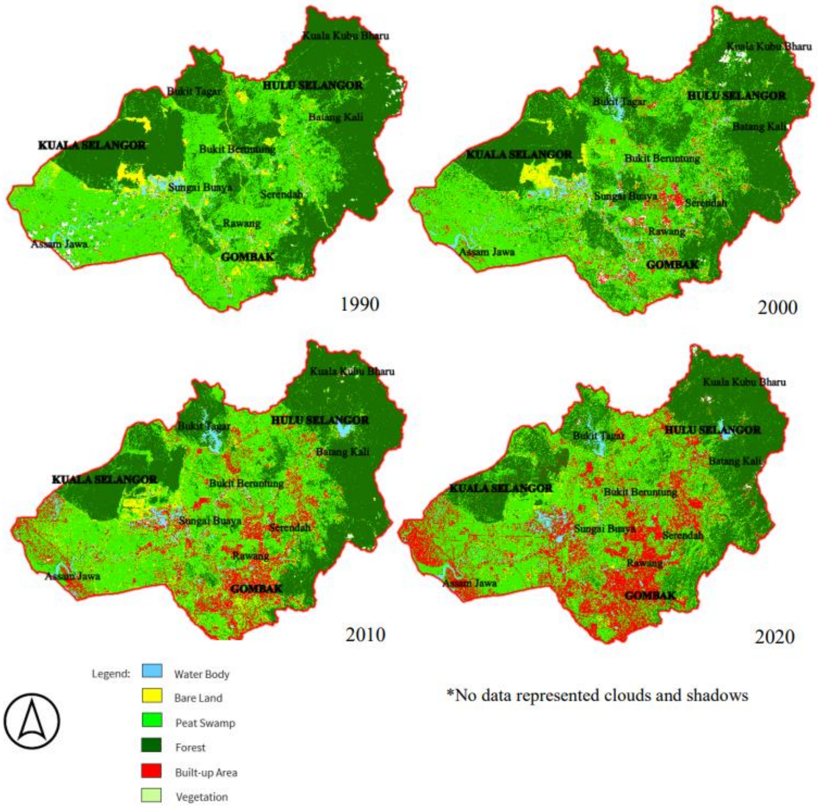

Figure 4. Distribution of land cover of Selangor river basin in the year studied

Table 3. Statistics of land-cover-changes at Selangor river basin

Class name	Area (h)	Area (%)	Transition (%)
Landsat 5 TM 1990			
Forest	108546.93	48.31	0
Built-up Area	1407.51	0.63	0
Bare Land	12368.34	5.50	0
Vegetation	96125.67	42.78	0
Water Bodies	4259.52	1.90	0
Cloud	1982.61	0.88	0
Landsat 7 ETM 2000			
Forest	106434.36	47.37	(0.94)
Built-up Area	9380.43	4.17	3.54
Bare Land	10519.11	4.68	(0.82)
Vegetation	89868.96	40.00	(2.78)
Water Bodies	5633.55	2.51	(0.61)
Cloud	2854.44	1.27	0.39
Landsat 5 TM 2010			
Forest	84174.03	37.46	(9.91)
Built-up Area	26210.61	11.67	7.50
Bare Land	13813.56	6.15	1.47
Vegetation	94151.97	41.90	1.90
Water Bodies	5499.45	2.45	(0.06)
Cloud	840.96	0.37	(0.90)
Landsat 8 OLI-TIRS 2020			
Forest	70239.33	31.26	(6.20)
Built-up Area	43128.27	19.19	7.52
Bare Land	9484.83	4.22	(1.93)
Vegetation	95994.27	42.72	0.82
Water Bodies	5469.39	2.43	(0.02)
Cloud	374.49	0.17	(0.20)

increased number of oil palm plantations and rubber estates, that have been established in Kuala Selangor through forest conversion (Mohammad, Sharifah Mastura, & Akhir *et al.*, 2007).

The bare land is also consistent from 12,368.34 ha^2 in 1990 to 10,519.11 ha^2 in 2000. However, in 2010, it was increased a bit to 13,813.56 ha^2 compared to 2000 due to land clearing or logging activities. Bare land is an indication of land in a particular area is cleared. However, in 2020, the bare land was reduced to 4 percent (9484.83 ha^2) from 2010, which might be due to the logging was not allowed in Selangor (25-Year Moratorium Policy).

A consistent percentage of water bodies can be seen throughout these three decades. The decreased of water bodies in 2010 and 2020 are due to the sand mining activities, that happened near Sungai Kuantan from 2017 to 2018 (Junaidi, 2018; MStar, 2018) that has impacted the habitat and number of fireflies.

Thus, it shows that the driving force of demography and economy through urbanization have influenced the pressure of forest loss in the Selangor River Basin area, which has significantly increased. It can be proven by the result of the land cover changes analysis in the study area. Such changes indicate that the river basin has experienced urbanization and will continue to do so unless strict measures are taken.

Due to significant construction activities, more bare land and forest in the study area were converted into built-up area and vegetation as the area grew more densely populated. Also identified is that the forest in the study area continued to show a pessimistic distribution trend, proving the decline of both elements (Lembaga Urus Air Selangor [LUAS], 2014; Nurhidayu *et al.*, 2016). Nonetheless, as more built-up areas increased, including housing, business, road networks, and other human activities in the area, a sprawl pattern began to emerge. Built-up areas tend to spread within the Selangor River Basin, covering most of the forest area, resulting in a substantial reduction in woodland in the area. The decreasing trend of forest, bare land, and water bodies was generally linked to the increasing pattern of built-up areas.

DPSIR framework (Figure 5) was derived to present the indicators needed for the policymakers for the development of policies in the future. The findings suggest that the concerns will be toward the demography, economy, deforestation, land use, physical state, ecosystem, environment, strategy, and policies for the framework.

Under driving force, it can be seen that anthropogenic activities occur due to population growth and economic growth. Land clearing, agriculture and mining are considered amongst the driving forces of this site. On the other sides, pressures are characterized by the natural resources and waste deposited in the environment (Troian, Gomes, Tiecher, Berbel, Gutiérrez-Martín, 2021). Sources of waste of land clearing and waste from the nearby industrial area have been transported to the river. The framework has also evaluated the state of the environment. However, this study is concerned with the physical and ecosystem, by highly use of environmental resources in land conversion and water resources. In addition, impacts that changing the state including economy and environment, by losing many scenic and natural environment to human activities. Lastly, responses to the impacts such as forest protection and strengthening related policies will be considered in this study.

5. Conclusions

The four-stage period analysis revealed a variable rate of land-cover changes in the Selangor River Basin. The forests have been steadily shrinking since 1990, with an annual decline of 17 percent from 1990 to 2020. Overall, the extension of built-up areas in the Selangor River Basin has had a significant impact on land-use changes and stimulated the enhancement of developments, with approximately 18 percent more areas. As a result, this study reveals that urban growth happened significantly in the study area's south, notably in Rawang, Serendah, and Kuala Selangor. To reduce the possibility of undesirable consequences, it is necessary to concentrate on development strategies. In addition, this research presents a DPSIR framework model to give relevant indicators and allow policymakers to respond to future environmental challenges in policy design. It is important to conduct a more in-depth analysis of the effects of forest loss and the increase in built-up area in the Selangor River Basin.

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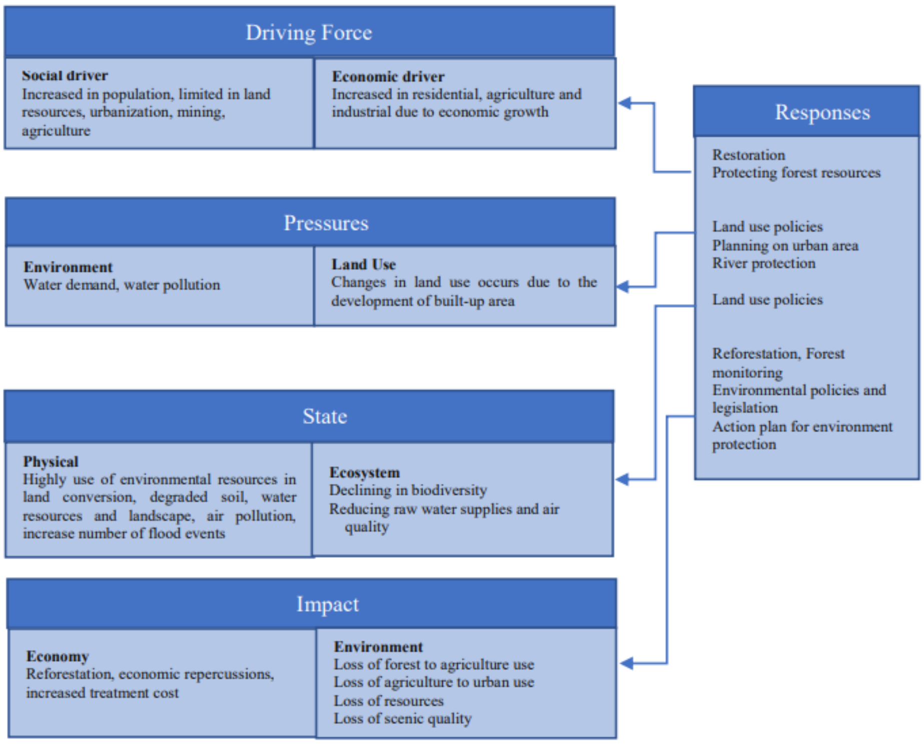

Figure 5. DPSIR framework model of this study

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