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DPSIR¹ model approach to address land-use changes in Deli Serdang District, North Sumatera Province

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Abstract. Deli Serdang Regency is bordered by Medan City, Langkat, Karo, Simalungun, and Serdang Bedagai Districts, North Sumatera Province. This study aimed to analyze land-use changes during ten years period in Deli Serdang District. Land-use changes were spatially analyzed using Geographic Information System (GIS). The factors causing land-use changes, the Driving Force, Pressure, State, Impact and Response (DPSIR) models were used. The results showed that within an interval of ten years (2009-2019) there were land-use changes in Deli Serdang. The area of land use had increased, including: Mangrove forest (4,589.56 ha to 5,645.23 ha), industry (2,470.52 ha to 3,316.39 ha), open land (361.11 ha to 1,451.04 ha), Plantation (80,649.32 ha to 88,411.56 ha), settlement (21,596.50 ha to 23,581.43 ha) and shrubs (2,332.16 ha to 3,013.33 ha). The area of land use that were reduced include dryland forests, mixed gardens, cultivation, paddy fields and ponds. The increasing open land and industry, the reduction in the vegetation area, especially forests, are the important issues in climate change because forests acts as carbon absorber. Based on the DPSIR analysis, population increase is a trigger factor for land-use changes in Deli Serdang Regency.

1. Introduction

Deli Serdang Regency is one of the areas in North Sumatera that has always been experienced an increase in population [1][2]. Such affects on increasing in space requirement, which includes the need for a place to live, a place to work and other basic infrastructures. This space requirement is one of the factors that influence land-use change. One of the land use that often changes is forest, which is an important problem that must be considered because it can absorb carbon. Therefore forest cover needs to be maintained, thereby reducing the impact of climate change.

Deli Serdang Regency is bordered by Langkat Regency and the Malacca Strait in the North, Karo and Simalungun Regency in the south, Langkat and Karo Regency and Binjai City in the West, and Serdang Bedagai Regency in the East. Deli Serdang Regency surrounds Medan City, which is the capital of North Sumatera Province. As a regency directly adjacent to Medan City, many of residents who work in Medan City also live in Deli Serdang Regency. As a result, population in Deli Serdang Regency has

¹ Driving Force, Pressure, State, Impact and Response



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increased. Population growth increases every year, and the intensity of development in various fields will increase land demand. This problem will trigger sustainable community interaction with land in meeting the needs of the surrounding community. The interactions between communities and land that cause changes to land-use potentially impact the sustainability of land resources

Thus, it is necessary to monitor land-use changes so that the impacts of land-use change can be solved and resources management in the future can be planned by optimizing the benefits of the resources sustainably land-use is a form of human interaction with land to meet their material and spiritual needs. Several studies related to land-use have been carried out [3][4]. The latest data and information regarding land cover changes that have occurred in Deli Serdang Regency are needed. Good policies are needed to minimize land conversion into various uses. Supporting information is needed for this policy to analyze land-use changes in this area. Furthermore, tools are needed to analyze the causes of land cover change. One of the approach tools that can be used is DPSIR Model. DPSIR was discovered and developed by the European Environmental Agency (EEA) in 1999 [5]. The ministry of environment and forestry has also used this model as a tool to analyze environmental problems.

Study of land-use types and monitoring of land-use changes are necessary to determine the direction of long-term development and are beneficial for preserving land resources. To support these efforts, it is necessary to have technology that can provide information about land-use changes periodically [6]. Therefore with the technology, it is necessary to assess and monitor land changes in Deli Serdang Regency and what factors cause land-use changes. One of the most important technologies in management today is using spatial data and geographic information systems to improve land management systems' accuracy and effectiveness. Given the importance of data and information regarding land-use changes during ten years is necessary. This study aimed to analyze land-use change based on the Driving Force, Pressure, State, Impact and Response (DPSIR) model. This study's results are expected to be input for stakeholders, especially the Deli Serdang district government in planning and management of the area.

2. Methods

This research was conducted in Deli Serdang Regency (Figure 1). Data analysis was carried out at the Forest Inventory Laboratory, Faculty of Forestry, Universitas Sumatera Utara. Research materials were administrative digital map of Deli Serdang Regency, land cover map of 2009 and 2019. And, research tools were computers, ArcGis software, Global Positioning System (GPS), and digital cameras.

The implementation of this research includes primary and secondary data. The land cover analysis in Deli Serdang Regency in 2009 and 2019 was carried out using a geographic information system (GIS) application [6][7]. To analyze land cover change every year, the change detection was analyzed using GIS application. Field survey (ground check) was conducted to ensure the land cover type's accuracy from the land cover map. The observation points were taken by using a GPS. Interviews with key respondents and discussions with stakeholders were also conducted in order to collect data for analysis. Analysis of the DPSIR model was conducted to determine the causes, impacts, and responses made to land cover change problems that occurred in Deli Serdang Regency.

3. Results and discussion

Land-use change analysis in Deli Serdang Regency using DPSIR Model was described through the DPSIR analysis diagram of land cover changes in Deli Serdang Regency (Figure 2).

3.1. Driving force

Based on Figure 2, the driving force for changes in land cover in Deli Serdang Regency was population growth [1], as presented in Figure 3. The increase in Deli Serdang Regency population from 2016 to 2018 was in three sub-districts, namely: in Percut Sei Tuan, Sunggal, and Tanjung Morawa. The increase in the population became a driving force for inducing and increasing human needs for food and others generated by land resources. Likewise, there would be a demand for non-agricultural products such as housing needs and regional infrastructure. This increased population growth and increased material

requirements were likely to lead to competition in land use. Changes in land use in development implementation cannot be avoided. Also, accessibility increase of land use in Deli Serdang Regency also triggers land-use change. The increasing number of roads in Deli Serdang Regency in 2017-2018 were dominated by small roads with a total length of 3,670.71 kilometers [8].

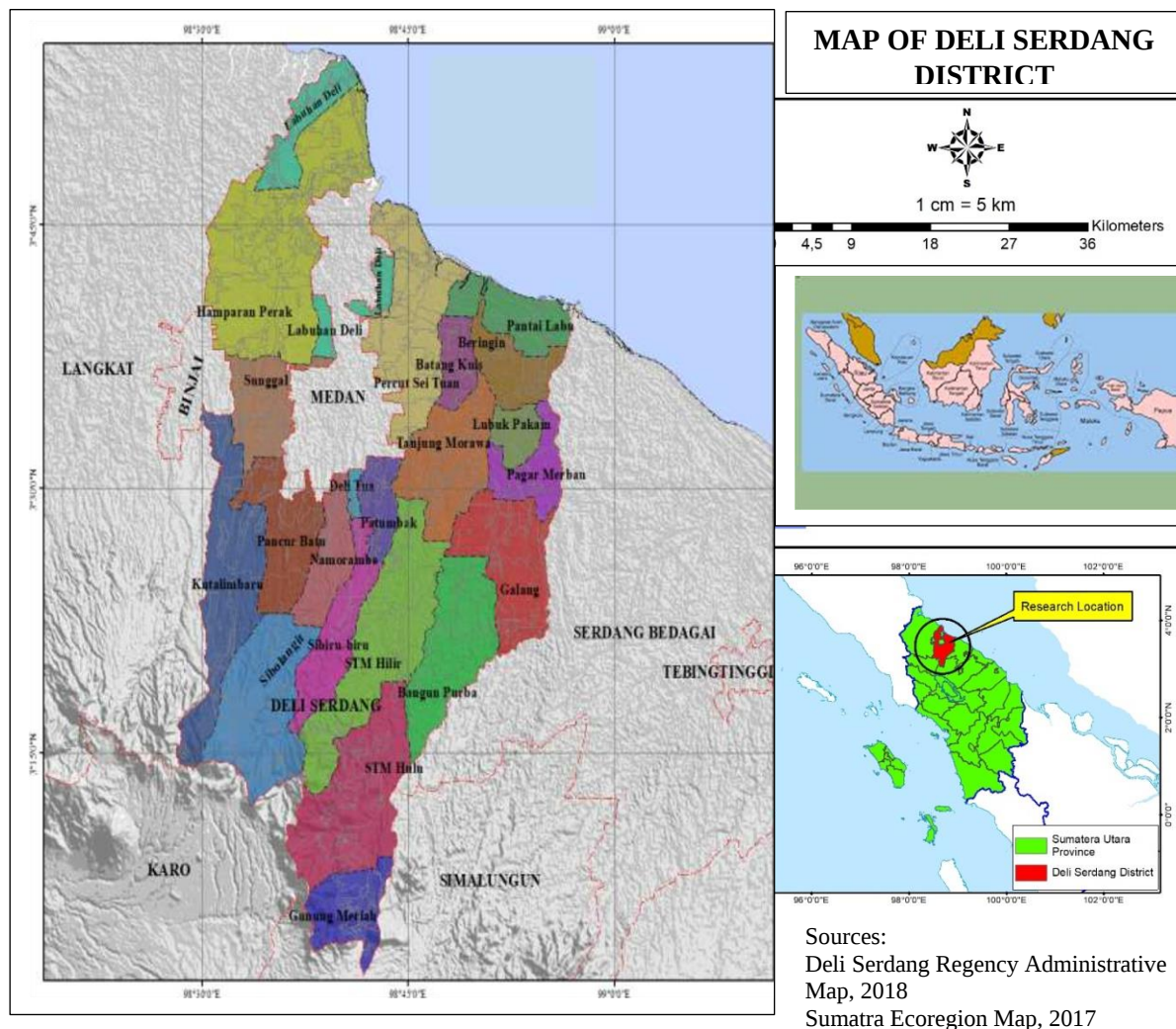


Figure 1. Research location

3.2. Pressure

Based on Figure 2, one of the pressures for the environment in Deli Serdang Regency was the change in land cover. Land-use change area in Deli Serdang Regency can cause various pressures on the environment, such as pressure on land, pressure on forest areas, pressure on biodiversity, and pressure on the function of forest ecosystems [8]. This problem was related to the increase in population, resulting in increased demand for land for various purposes. This increasing need threatens the existence of land resources. The increasing need for land had resulted in increasing forest land clearing.

3.3. State

The land-use map analysis results showed that there were 12 types of land cover in Deli Serdang Regency (Table 1). Land cover in Deli Serdang Regency was dominated by Plantation followed by Mixed garden and paddy fields.

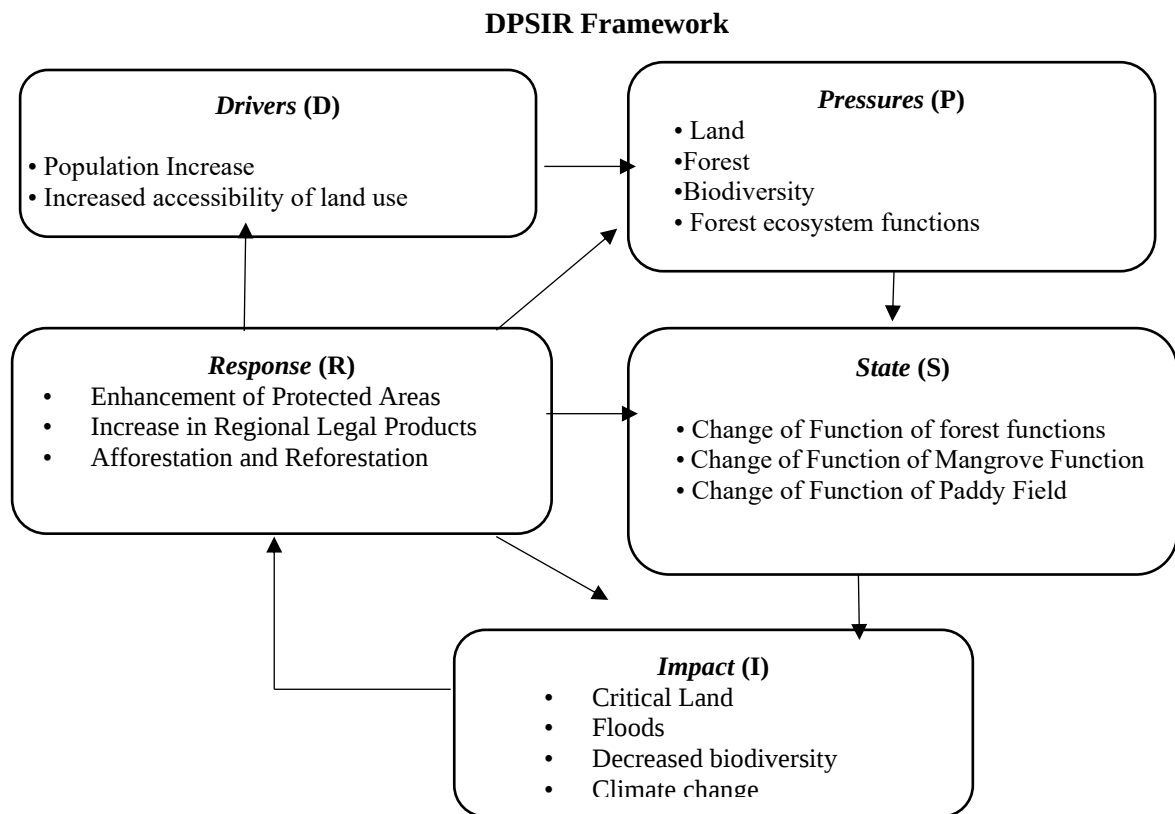


Figure 2. DPSIR analysis diagram related to changes in forest land cover in Deli Serdang District [5]

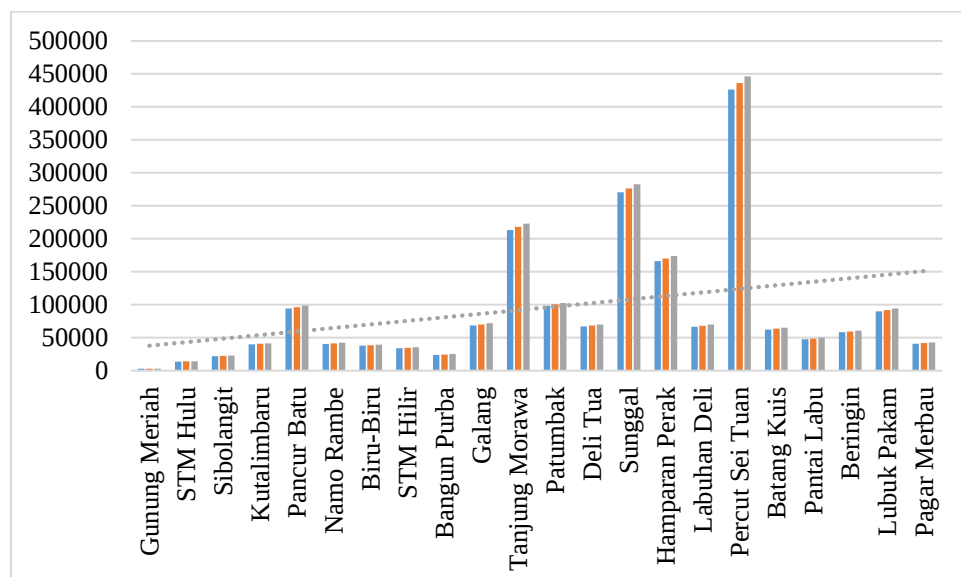


Figure 3. The increase in sub-district population in Deli Serdang Regency 2016-2018. Blue=2016; Red=2017; Gray=2018 [1][2]

Table 1. Area of land cover for ten years in Deli Serdang Regency

Land Cover	Area (ha)		Changes	
	Year 2009	Year 2019	Increase (%)	Decrease (%)
Cultivation	25,476.14	24,383.63		0.42
Dryland forest	19,517.58	19,426.73		0.04
Industry	2,470.52	3,316.39	0.33	
Mangrove forest	4,589.56	5,645.23	0.41	
Mixed garden	52,396.87	49,603.82		1.08
Open land	361.11	1,451.04	0.42	
Paddy field	39,876.06	34,574.82		2.05
Plantation	80,649.32	88,411.56	2.99	
Pond	8,029.19	3,887.05		1.6
Settlement	21,596.50	23,581.43	0.77	
Shrubs	2,332.16	3,013.33	0.26	
Water body	1,644.55	1,644.55		
Total	258,939.57	258,939.57		

The area of land-use had increased, including mangrove forest (4,589.56 ha to 5,645.23 ha), industry (2,470.52 ha to 3,316.39 ha), open land (361.11 ha to 1,451.04 ha), Plantation (80,649.32 ha to 88,411.56 ha), settlement (21,596.50 ha to 23,581.43 ha) and shrubs (2,332.16 ha to 3,013.33 ha). The area of land use that was reduced, including: dryland forests (19,517.58 ha to 19,426.73 ha), mixed gardens (52,396.87 to 49,603.82), cultivation (25,476.14 to 24,383.63), paddy fields (39,876.06 to 34,574.82), and ponds (8,029.19 to 3,887.05). The increase in area occurred in plantations (+ 2.99%) followed by settlement (+ 0.77%). The largest decreasing area was the paddy field (-2.05%), followed by the pond (-1.6%). Based on Figure 2, the increasing population growth triggered land-use changes in Deli Serdang Regency.

Based on Table 1, over a period of ten years, there has been an increase in the area of mangroves, plantations, and shrubs (3.66%). On the contrary, for ten years, there had been a reduction in the area of vegetation such as dryland forest, cultivation, paddy fields, and mixed garden (3.59%). The difference between increasing and decreasing vegetation area in Deli Serdang Regency was only 0.07%. Thus, during ten years of vegetated land cover in Deli Serdang Regency, it increased by 0.07%. This situation needs to be maintained and enhanced in order to reduce the impact of climate change. As agree with some research results, vegetation plays an important role in reducing climate change [6][9].

The plantations in Deli Serdang Regency are scattered in almost all districts. Generally, it is dominated by oil palm and rubber plantations [1][2]. The plantation commodity that is experiencing rapid development, namely oil palm plantations, is currently shifting rubber plantations' position. The mangroves in Deli Serdang Regency had increased by 0.41%. The area of mangroves in four sub-regencies in Deli Serdang Regency had increased in the last ten years. This increase was due to the large number of pond businesses that were no longer utilized and abandoned, so the pond area grew mangrove vegetation naturally. The pond had decreased by 1.6% over ten years. Also, Mangroves had turned into industry, cultivation, plantations and open land, even in a small area, so the total increased due to unmanaged ponds. The decline in land use was also found in paddy fields, namely in 2009 covering an area of 39,876.06 and in 2019 to 34,574.82 ha, so it can be concluded that in 2009 and 2019 there was a decrease in land-use area by 2.05% use of paddy fields in Deli Serdang Regency.

3.4. *Impact*

Within ten years, there had been a change in land-use that triggered climate change as a result of changing vegetated land to industry, including cultivation into industry, 376.22 ha, open land 387.04 ha and settlement 886.99 ha. Dryland forest to open land was 46.02 ha and shrub was 12.18 ha. Mangroves to industry, open land, and shrub were 59.08 ha, 20.73 ha, and 57.85 ha, respectively. Mixed garden to industry was 190.22 ha, open land was 199.84 ha, and settlement was 444.47 ha. Paddy field to industry was 123.69 ha and settlement was 398.87 ha, and shrubs were 120.28 ha. Some of the impacts of land cover change in Deli Serdang Regency include critical land, flooding, and climate change [8]. Another impact was flooding due to the catchment area being unable to infiltrate water into the ground as an impact of open areas.

Land-use change also have impact on climate change. Deli Serdang Regency area is influenced by two seasons, namely the dry season and the rainy season. From June to September, the winds that blow do not contain much moisture, resulting in a dry season. On the other hand, from November to March, the wind contains a lot of water vapor, so that the rainy season occurs. This situation changed after passing the transitional period in April-May and October-November [8].

Reduction of vegetation area, especially forests, is an important issue in climate change. Because forests can absorb carbon [10][11]. Deforestation can cause a loss of flora and fauna in natural forests and disrupt forest functions that can absorb Carbon dioxide (CO₂) in the air and release Oxygen (O₂). CO₂ is a greenhouse gas that can cause global warming. Absorption by plants is one way to reduce CO₂ emissions [10][12]. Carbon dioxide emissions are the emission or discharge of CO₂ gas into the air [12] in reducing vegetation, especially forest cover which is a problem associated with climate change because forests can absorb carbon [9][10][12][13].

3.5. *Response*

One of the efforts to overcome land-use change problems such as critical land and climate change in Deli Serdang District is by planting trees. Trees and forests have an important role in tackling climate change, such as a green belt in Medan City [6] and tree planting in city parks [14]. To reduce the impact on climate change, besides planting trees, it is necessary to strive hard by reducing deforestation and forest degradation [3]. The efforts of the government to change forest land cover is to increase the protected areas. Based on the trend of increasing population in the last three years, which can result in land conversion that threatens the environmental conditions in Deli Serdang Regency, the government has made various efforts to deal with this condition.

Reforestation has been carried out by the Government of Deli Serdang Regency [8] to thwart the impacts of climate change, increase groundwater infiltration [15], and strengthen soil through tree roots and increase CO₂ uptake in anticipation of natural disasters. In 2018, the area where afforestation was conducted reached 75 ha, and the area for reforestation was 115 ha [8]. The sub-regency with the most realization of these activities were Sibolangit and Sinembah Tanjung Muda (STM) Hulu. Meanwhile, the number of trees planted in 2015 indicated 382,644 trees, and in 2018 around 230,344 trees [8].

4. **Conclusion**

Within ten years, a change in land cover was observed in Deli Serdang Regency. Among the land cover areas that have increased include industry, mangroves, open land, plantations, settlements, and shrubs, whereas those areas that have decreased are the cultivation area, dryland forest, mix garden, paddy field, and pond. Changes in land cover in Deli Serdang Regency were triggered by an increase in population and an increase in the accessibility of land use. This raises pressures (P) on land, forest areas, biodiversity, and the functions of forest ecosystem which cause critical land, flood disasters, decrease in biodiversity as a result of climate change. Over ten years, the total vegetated land cover in Deli Serdang Regency increased by 0.07%. This situation needs to be maintained and improved in order to reduce the impact of climate change. This research does not stop here because of the dynamics of changes that will occur, so further research is still needed in the next years to determine changes in land cover, especially vegetation in this area.

Acknowledgment

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