Land use directions based on the level of land conversion vulnerability in the Padang Watersheds, North Sumatera

S A Purba¹, B Slamet²* and A Rauf³

¹Graduate School of Natural Resources and Environmental Programs, Universitas Sumatera Utara, Medan, North Sumatra, Indonesia 20155
²Faculty of Forestry, Universitas Sumatera Utara, Medan, North Sumatra, Indonesia 20155
³Faculty of Agriculture, Universitas Sumatera Utara, Medan, North Sumatra, Indonesia 20155

*Email: bejo@usu.ac.id

Abstract. Hazardous land conversion in the Padang watersheds harms the hydrological conditions of the watersheds. Land use without considering the capacity and carrying capacity of the land results in decreased land productivity and increased watershed damage. This study aims to recommend directions for land use and land management in the Padang watersheds in areas that have a high and very high level of land conversion vulnerability. Analysis of land conversion vulnerability obtained by spatial modeling using ArcGis 10.3 software. The land cover data used in this study are data from the Ministry of Environment and Forestry in 2000 and 2019. Directions for land use are carried out through literature review in scientific journals, activity reports from both government and non-government agencies. Recommendations for land management directions are differentiated for urban areas and non-urban areas. Shrub cover that is vulnerable to conversion so that reforestation or other productive land uses are carried out with attention to soil and water conservation. Secondary dryland forest cover that is very vulnerable to conversion is suitable for partnerships with communities through community forestry/agroforestry schemes, rehabilitation and reforestation, and ecotourism. Plantation cover that is vulnerable to conversion can adopt an intercropping pattern of garden crops and seasonal crops. Agricultural land cover of dry land with high conversion vulnerability can adopt perennial crops at the land boundary and apply soil and water conservation. Residential areas in rural areas can adopt tree planting and make infiltration wells. The management direction for residential land in urban areas is to apply water conservation techniques (infiltration wells and polders) and arrangement of residential areas.

1. Introduction

Land conversion is one cause of damage to watersheds, which raises complex problems in physical, economic, and social good. Land conversion into land use that is not following its capacity and carrying capacity results in watershed damage. The impacts that occur are soil erosion, sedimentation, river flow fluctuations (floods in the rainy season and drought in the dry season), and decreased land productivity [1-3]. Humans are the main factor determining whether land conversion can have a negative or positive impact.

High population growth and low levels of community income are among the factors that trigger land conversion activities that do not pay attention to the principles of soil and water conservation.
Land use that is following the capacity of the land will maintain the carrying capacity of the watersheds in good condition. A good watershed carrying capacity will be able to provide support for the life of living things in the watersheds. The land conversion that is not following the spatial pattern that is allowed to continue can be ascertained that it will increase the area of critical land, erosion, flooding, and decrease land productivity which results in the decreased carrying capacity of the watersheds [4-6]. Incidents like this occur in almost all watersheds areas from upstream to downstream.

Conversion of vegetated land cover will reduce the ability of the land to absorb, store, and distribute rainwater in the rainy and dry seasons. The continued effect of watersheds with high land conversion vulnerability is an increase in the sedimentation rate and a decrease in water quality. Decreasing river water quality harms river ecosystems and reduces the possibility of its use for humans. [7] stated that land conversion, together with increased population growth, has increased the vulnerability of water quality in various catchments. The clearing of natural vegetation and the transformation of natural land use into urban development lead to increased runoff and sediment loads, which also facilitate the transfer of pollutants from soil to water. Land use activities that are not following the capacity of the land will cause watershed degradation. [8-10] stated that the increased critical land area was caused by land management that was not following its capabilities and was not accompanied by soil and water conservation efforts.

One of the causes of the conversion of agricultural land to non-agricultural is the result of policies to develop centers of economic growth, trade, and tourism. The land conversion that causes environmental damage is the conversion of forest land to agriculture or settlements. Land changes to settlements usually come from paddy fields (irrigated or rainfed), fields, moor, and plantations [11]. Changes in forest land cover into cultivated land, settlements, shrubs, or open land have the potential to become critical land [12]. Analysis of land-use change by utilizing spatial data that is temporal in nature is very useful, especially to find out the locations of places where land-use changes occur so that the level of vulnerability to land conversion can be analyzed [13].

The Padang watersheds are located in three districts/cities, namely Simalungun Regency, Serdang Bedagai Regency, and Tebing Tinggi City. [14] reported that the level of land conversion vulnerability in the Padang watershed was dominated by the vulnerable class of 50.38% or 55,584.54 Ha and the very vulnerable class of 27.38% or 30,213.97 Ha. With the percentage of areas that have a land conversion hazard class that is very vulnerable and vulnerable to This study aims to recommend directions for land use and land management in the Padang watersheds in areas that have a high and very high level of land conversion vulnerability. This information is expected to help the community adopt environmentally friendly land use in the Padang watershed area.

2. Research Methods
This research was conducted from August to September 2020 located in the Padang watersheds which includes Simalungun Regency, Serdang Bedagai Regency, and Tebing Tinggi City, North Sumatra Province. The data used are primary data on the condition of the cover and land management in the field obtained from taking points in the field using GPS. Secondary data was in the form of land cover data and maps of the Padang watershed from KLHK. The data on the level of vulnerability were obtained from the research of [14].

Processing of spatial data in this study using Arc Gis 10.3 software. Land conversion analysis based on land cover data for 2000 and 2019 from KLHK. Furthermore, the direction of land use is carried out through a literature review in scientific journals, activity reports from both government and non-government agencies. Recommendations for land management directions are differentiated for urban areas and non-urban areas [15-20].

3. Results and Discussion
During the period 2000 to 2019, the land cover with a high conversion rate was mixed dryland agricultural cover, which decreased in area by 49.23%. 46.64% of this area became the dryland
agricultural cover, with 1.68% being converted to rice fields and 1.44% being converted to plantations (Table 1).

Plantation and rice fields also experienced an increase in the percentage change, which is 1.44% in plantations and 1.68% in rice fields. [15] stated that land use directions for the use of rice fields, plantations, and dryland agriculture can be done with an agroforestry system, namely planting forestry plants combined with crops. Spatial arrangements for forestry crops planted on the edge/boundary of land owned by farmers. For plantation land use, that is, with an intercropping pattern between seasonal plants and annual trees. Meanwhile, dry land agriculture is directed to plant annual trees as the boundaries of land owned by farmers. Land use distribution in Padang Watersheds can be seen in figure 1.

![Figure 1. Land cover map in Padang watersheds in year 2000 and year 2019](image_url)
### Table 1. Land cover change in the Padang Watersheds Period of 2000-2019

| Land Cover | Year 2000 (Ha) | Year 2019 (Ha) | Difference 2019-2010 (Ha) | Percent Change (%) |
|------------|----------------|----------------|---------------------------|--------------------|
| Water      | 452.29         | 458.46         | 6.17                      | 0.01               |
| Shrub      | 7,161.02       | 7,162.42       | 1.40                      | 0.00               |
| Swamp bush | 59.14          | 31.54          | -27.60                    | -0.03              |
| Secondary dryland forest | 7,505.60 | 7,433.78 | -71.82 | -0.09 |
| Secondary mangrove forest | 661.40 | 370.81 | -290.59 | -0.36 |
| Settlement | 2,187.22       | 2,206.71       | 19.49                     | 0.02               |
| Plantation | 38,662.70      | 39,841.68      | 1,178.98                  | 1.44               |
| Dry land farming | 6,641.01 | 44,563.72 | 37,922.71 | 46.46 |
| Mixed dry land farm | 40,184.00 | 0.00 | -40,184.00 | -49.23 |
| Rice field | 5,265.12       | 6,632.69       | 1,367.57                  | 1.68               |
| Pond       | 206.00         | 526.12         | 320.12                    | 0.39               |
| Open Area  | 1,354.11       | 1,111.78       | -242.33                   | -0.30              |

The level of vulnerability to land conversion in the Padang watershed is classified into 5 classes, namely Very not vulnerable, not vulnerable, moderate vulnerable, vulnerable, and very vulnerable [14]. Areas with a vulnerable, and very vulnerable level of conversion must be given recommendations for land use directions to suit their land ability class (Table 2).

### Table 2. Ideal recommendations for land management based on the land conversion vulnerability in the Padang Watersheds in 2019

| Region Regency/City | Vulnerability | Land Cover | Area (Ha) | Management Recommendations |
|---------------------|---------------|------------|-----------|---------------------------|
| Serdang Bedagai     | Vulnerable    | Water      | 156.88    | Protection and preservation of water sources, management of water quality, control of water pollution |
|                     |               | Shrub      | 635.11    | Reforestation |
|                     |               | Swamp bush | 30.06     | Reforestation |
|                     |               | Secondary dryland forest | 0.16 | Community forestry patterns or agroforestry, ecotourism. |
|                     |               | Secondary mangrove forest | 200.22 | Community forestry patterns or agroforestry, ecotourism |
|                     |               | Settlement | 165.07    | Planting trees/vegetation in the yard of the house and constructing infiltration wells |
|                     |               | Plantation | 16.858.77 | Intercropping of garden crops and seasonal crops, soil and water conservation |
|                     |               | Dryland    | 12.539.39 | Planting perennial trees on land |
| Region Regency/City | Vulnerability | Land Cover | Area (Ha) | Management Recommendations |
|--------------------|--------------|-----------|-----------|---------------------------|
|                    |              | farming   | boundaries, applying soil and water conservation techniques both vegetative and civil engineering |
| Rice field         |              | 3.234,82  | Agroforestry, optimization, and intensification of rice fields |
| Pond               |              | 187,51    | Silvofishery |
| Open area          |              | 726,59    | Reforestation, application of soil and water conservation techniques |
| Very Vulnerable    | Water        | 189,18    | Protection and preservation of water sources, management of water quality, control of water pollution |
| Shrub              |              | 113,55    | Reforestation |
| Settlement         |              | 247,17    | Planting trees/vegetation in the yard of the house and constructing infiltration wells |
| Plantation         |              | 11.392,94 | Intercropping of garden crops and seasonal crops, soil, and water conservation |
| Dryland farming    | Rice field   | 2.475,93  | Agroforestry, optimization, and intensification of rice fields |
|                   | Open area    | 189,4     | Reforestation, application of soil and water conservation techniques |
| Simalungun Vulnerable Shrub | Secondary dryland forest plantation | 1.216,75 214,71 | Reforestation Community forestry patterns or agroforestry, ecotourism. |
| Dryland farming    |                    | 1.653,43  | Intercropping of garden crops and seasonal crops, soil, and water conservation |
|                   | Open area      | 92,51     | Reforestation, application of soil and water conservation techniques |
| Very Vulnerable    | Shrub         | 96,68     | Reforestation Community forestry patterns or agroforestry, ecotourism. |
| Secondary dryland forest plantation |                    | 1.03 | Intercropping of garden crops and seasonal crops, soil, and water conservation |
| Dryland farming    |                    | 1.525,55  | Planting perennial trees on land boundaries, applying soil and water conservation |
| Region Regency/City | Vulnerability | Land Cover | Area (Ha) | Management Recommendations |
|--------------------|---------------|------------|-----------|---------------------------|
| Regency/City       |               |            |           | conservation techniques both vegetative and civil engineering |
| Open area          | 32.79         | Reforestation, application of soil and water conservation techniques |
| City of Tebing Tinggi | Very Vulnerable | Water       | 95.84     | A clean water management system must include the principle of sustainability |
| Settlement         | 1.794.47      | Water conservation techniques (infiltration wells and polders), the arrangement of residential areas |
| Plantation         | 157.97        | Intercropping of garden crops and seasonal crops, soil, and water conservation |
| Dryland farming    | 1.485.52      | Annual crop planting in the land boundaries, soil, and water conservation |
| Rice field         | 437.46        | Optimization and intensification of rice fields |
| Open area          | 18.67         | Green open space for water absorption function, provision of green pedestrian paths. |

The plantations cover in Serdang Bedagai Regency with an area of 16,858.77 hectares has vulnerable land conversion class, dryland agriculture in Simalungun Regency with an area of 12,357.29 hectares and settlements in Tebing Tinggi City covering an area of 1,794.47 hectares (Table 2). The cover of shrubs in Simalungun Regency with classes vulnerable to conversion to other uses is 1,216.75 hectares. The main causes of land conversion in the upstream area are economic factors and the need for wood for firewood. Some residents in the upstream Padang watershed still use wood as their daily fuel.

In the upstream Padang watersheds, there are natural forests and secondary forests that must be protected. Recommendations for land management for preventing land degradation in the Padang watersheds are reforestation (afforestation) and soil and water conservation, both vegetative, agronomic, and management [16,17]. Besides, agroforestry systems are a solution to deforestation and land degradation. Agroforestry is a farming system that combines woody trees with crops such as fruit and plantation crops which have hydrological functions not much different from forest plants. The agroforestry system aims to improve the welfare of local communities through optimal, equitable, and sustainable use of forest resources (Ministerial Regulation No. P.88 / Menhut-II / 2014). Agroforestry development has a good prospect, especially it is hoped that it can help sustainably optimize land use to guarantee and improve the people's living needs and can increase the carrying capacity of human ecology, especially in rural areas [18]. Agroforestry cropping patterns can increase land productivity, farmers’ income, support food security, and reduce the occurrence of surface runoff and flooding [18-20]. To anticipate the expansion of forest land conversion to other (non-forest) uses, this can be done through reforestation and rehabilitation of degraded land. One of the efforts to use degraded land is ecotourism that involves communities around the forest. The community can protect the forest area as well as receive economic benefits.

For rice fields that are vulnerable to conversion, suitable land use directions are patterns of intensification and planting of productive trees on land boundaries. Production of existing rice fields is maximized so that there is no land expansion/extensification [15]. The recommendation for residential
land management is the application of water and soil conservation techniques. Savitri and Pramono [21] state that the most suitable water conservation techniques for settlements in urban areas are infiltration wells and polders, while settlements in rural areas can combine tree planting and making infiltration wells.

4. Conclusion
Recommendations land management directions are distinguished for urban areas and non-urban areas. Ideally, the recommendations given for all land uses are the same unless they are used. To prove that there is no planting of trees/vegetation in the yard of the house and the construction of infiltration wells. Meanwhile, for urban dwellings, water conservation techniques (infiltration wells and polders) as well as regional regulation. Further studies are needed to be applied in the field.

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