The spatial degradation of Riceland and farmers perception of its causal factors and strategic adaptations

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Abstract. Deli Serdang District is among the highest rice producer districts in North Sumatera Province. Unfortunately, climate change and improper cultivation management practices degrade riceland fertility and affect stagnant rice productivity over the years. This study aims to identify the spatial pattern of the limited-factors for riceland suitability and determine land degradation factors and the strategic actions to increase rice production. This study was conducted in 2019 in six districts and interviewed sixty farmers for getting information about riceland degradation issue. The field survey, soil analysis and household-based survey are some methods implemented in this study. The two tools, ArcGIS and SPSS, were used to gain the purposes of the research. The results show that the low status of nutrient availability, root condition and nutrient retention are the main factors of riceland degradation. Besides, this study found that climate change, lack of organic fertilizer implementation, water scarcity and excessive chemical fertilization implementation were significant factors of land degradation based on farmers perception. In addition, some of the strategic actions were frequently implemented to minimize the degradation rate are implementing the minimum tillage, using certified seed, giving a fallow season for riceland and recycling plant residue as organic fertilizer. The study suggests implementing the proper cultivation management practices like Integrated Crop Management (ICM) and Climate Smart Agriculture (CSA) to achieve the sustainability of rice production.

1. Introduction

Rice is an important agricultural commodity for the Asian people, including Indonesian. As the staple food, the rice needs continuously increase in line with the number of the populations. By considering the rice consumption rate of Indonesian people, 130.57 kg per capita [1], Deli Serdang District needs 281,378 tons of rice to fulfil 2.155 million people in 2019. Over the years, Deli Serdang District has the stagnant rice production due to the stagnant rate of productivity. Undoubtedly, the issue of rice sufficiency needs high priority concern in the future.

About 6 million ha of worldwide agricultural land annually became unproductive due to soil degradation issue [2]. While, a previous study reported that about 48.3 million ha or 25.1% of Indonesian land has degraded [3]. Land degradation is the reduction of soil capacity to produce crops or biomass for human beings and livestock [2]. Thus, strengthening the soil capacity itself is strongly related to increase physical, chemical and biological soil characteristics. Some of soil characteristics are texture,
pH, cation exchange capacity, organic carbon, total nitrogen, potassium and phosphor [4]. It may assume that the stagnant rice productivity in Deli Serdang District is affected by riceland degradation.

It is very important to identify the driving factors of riceland degradation, especially for the country/city who mainly depend on agricultural sector to support their livelihood. Some previous researches found the causal factors of soil degradation, such as, erosion [5,6], land use change [7,8], climate change [9], and population growth followed by urbanization [10]. In addition, improper land cultivation by farmers during cultivation may decline the soil fertility and affect land degradation. Improper land management may lead to the declining soil quality in some characteristics, such as, moisture, infiltration, structure; and surely it may give impact to the run off and erosion [11].

As the productive district for rice commodity, there are not so many previous researches conducted in Deli Serdang District focus on land degradation. Thus, we perform this study to identify the spatial pattern of land degradation and to determine the factors of land degradation and the strategic actions to increase rice production. By doing field survey, soil analysis and household-based survey, this study generates a spatial degradation map for riceland in Deli Serdang and determines the causal factors of riceland degradation and strategic adaptation to face the degradation issue based on farmers’ perception.

2. Methodology
Deli Serdang District is one of the districts in North Sumatera Province, which is located at 2° 57’ – 3° 16’ N and 98° 33’ – 99° 27’ E geographically. This district is bordered with Langkat, Karo, Simalungun, Serdang Bedagai District, Medan and Binjai Cities. It has about 2,497 km² for the total area that came from 22 total of districts [12]. It has elevation from 0 to 500 meters above sea level and has diverse topographical shapes from flat to mountainous.

Compare with other districts in North Sumatera Province, Deli Serdang District has a high potential for rice production. The rice production, which is generated from Deli Serdang District, has been distributing to others districts. Unfortunately, rice production is unmoving over the years due to stagnant productivity. The curiosity on the stagnant rice production in Deli Serdang District justifies choosing this district as the study location. The area of study location can be observed through Figure 1.

![Figure 1. Location of study area.](image-url)
There were two types of the survey conducted in this study: field survey and soil analysis and household-based survey. The first survey was conducted to observe the study area (slope and elevation) and compile soil data by collecting soil samples. These soil samples were sent to the laboratory and analyzed for some soil characteristics, such as texture (using hydrometer method), pH (using pH meter) [13], C-org (using spectrophotometric method) [14], N-total (using Kjeldahl method), P₂O₅ and K₂O (using atomic absorption spectroscopy method) [15]. Then, all survey data from each point were entered into the SPKL (“Sistem Penilaian Kesesuaian Lahan”) or the system of land suitability evaluation tool. This tool has a function to identify the limited factor to support rice growth [16]. All limited factors classified into 4 groups, namely: nutrient availability (na) (N-total, P₂O₅ and K₂O), nutrient retention (nr) (Cation Exchange Capacity, pH and C-org), root condition (rc) (soil texture and drainage condition) and erosion hazard (eh) (slope). Finally, these data were transferred to the ArcGIS to map spatial degradation especially for rice land. Meanwhile, the household-based survey was conducted to identify the causal factors of rice land degradation and the strategic adaptations to solve the issue. The questionnaire was prepared to gather information from 180 total respondents who came from six districts. Then, all data were input to the SPSS and analyzed using descriptive statistics.

3. Results and Discussion
3.1. Spatial degradation of rice land
This study was conducted at six districts of Deli Serdang District. These districts represent the total area of rice land from the largest (Percut Sei Tuan and Hamparan Perak Districts by 13,637 ha and 10,955 ha, respectively), the medium (Beringin and Sunggal District by 6,066 ha and 5,557 ha, respectively) and the smallest (Tanjung Morawa and STM Hilir District by 5,113 ha and 1,815 ha, respectively) [12].

Based on the result from field survey which is conducted in the study area and together with soil analysis, it can be detected that rice land degradation has occurred due to the low status of chemical and physical soil characteristics. Soil texture and drainage condition (rc factor) are the widest limited factor for rice growth by 64,953.2 ha or 36.2% of the total study area. Meanwhile, about 565.5 ha or 0.3% of the study area is the smallest degraded area with soil texture, drainage condition and slope as the limited factor (Table 1).

| Factors of rice land degradation | Total area (ha) |
|---------------------------------|-----------------|
| Nutrient availability (na)      | 9,303.6         |
| Root condition (rc)             | 64,953.2        |
| Erosion hazard (eh)             | 26,220.6        |
| Nutrient retention and nutrient availability (nr & na) | 7,851.2 |
| Root condition and erosion hazard (rc & eh) | 565.5 |
| Root condition and nutrient availability (rc & na) | 39,908.6 |
| Root condition, nutrient retention and erosion hazard (rc, nr & eh) | 8,250 |
| Root condition, nutrient retention and nutrient availability (rc, nr & na) | 21,088.8 |
| Root condition, nutrient retention, nutrient availability and erosion hazard (rc, nr, na & eh) | 1,155.7 |

It can be observed from Table 1 and Figure 2 that the study area was split by nine polygons with their specific limited factor. All districts in the study area mostly covered by rc, nr and na factors, except STM Hilir District. This particular district is located on the southern part of Deli Serdang District which is lied on the mountainous topography. Thus, STM Hilir has the slope as the limited factor for rice to grow. The slope below 3% is the highly suitable land for rice to produce, while 8-25% and higher 25% are categorized by low suitable and unsuitable, respectively [4].
Riceland degradation is one of the crucial issues facing by farmers, as the main involved-actor, in the field. Riceland degradation in Deli Serdang District has occurred in six districts with their specific limited factors. The soil physical and chemical fertility, specifically in the study area, has declined. Thus, this issue is one of the contributors to the stagnant productivity of rice.

![Spatial degradation of riceland area on study area](image)

**Figure 2.** Spatial degradation of riceland area on study area

### 3.2. The causal factors of riceland degradation

The causal factors of riceland degradation for this study was identified based on farmers perception which is gathered from household-based survey. The farmers, as the respondents, was divided into two groups, the respondents who have low rice productivity (< 4.0 tons/ha) and the respondents who have high rice productivity (> 4.0 tons/ha). Based on the result presented in Table 2, this study found that climate change was pointed out by 153 respondents as the highest contributor to the riceland degradation. Then, the lack of organic fertilization implementation into the riceland was chosen as well by 133 respondents as the causal factor of the riceland degradation. Last, 120 and 102 respondents designated the water scarcity and the excessive of chemical fertilization implementation as the responsible factors of riceland degradation, respectively. Meanwhile, more than 50% of respondents agree that there is no impact of the excessive implementation of chemical pesticide and mechanization tool on the riceland degradation in the study area.
Table 2. The causal factors of riceland degradation based on household-based survey.

| Causal factors                              | Number of respondents | Has low productivity | Has high productivity |
|---------------------------------------------|-----------------------|----------------------|-----------------------|
|                                            | Not agree | Agree | Not agree | Agree |
| 1. The water scarcity                       | 25        | 26    | 35        | 94    |
| 2. The excessive of chemical fertilization  | 23        | 28    | 55        | 74    |
| 3. The excessive of chemical pesticide      | 27        | 24    | 67        | 62    |
| 4. Climate change                          | 11        | 40    | 16        | 113   |
| 5. Lack of organic fertilization implementation | 12      | 39    | 35        | 94    |
| 6. Effect of mechanical tool                | 50        | 1     | 127       | 2     |

By comparing the spatial riceland degradation with the responses from the respondents, it can be observed that there is a significant relationship between this two information. There are four main causal factors behind the riceland degradation: climate change, lack of organic fertilizer implementation, water scarcity, and excessive chemical fertilization implementation. Climate change is a serious factor facing farmers globally. It shares negative impacts through drought, flood and erosion; and indeed, cause declining in soil fertility [9,17]. Besides, both the lack of organic fertilization and excessive chemical fertilization implementation undoubtedly cause the declining soil biological and chemical fertility faster [18]. These causal factors are the reason why the nutrient availability (na factor) (N-total, P₂O₅ and K₂O) and nutrient retention (nr factor) (Cation Exchange Capacity, pH and C-org) covered the study area dominantly.

3.3. The strategic adaptation for solving the riceland degradation

This study also found the common strategic actions were implemented by farmers to minimize the rate of riceland degradation which is gathered through a household-based survey (Table 3). The result presents that 163 and 160 farmers, who have low and high productivity, appoint the implementing the minimum tillage and using certified seed as their strategic action, respectively. In addition, 150 and 142 respondents choose giving a fallow season for riceland and recycling plant residue as organic fertilizer to solve this degradation issue. Unfortunately, not too many respondents choose the strategic adaptation of applying water efficiency, using water pump, applying organic fertilizer and constructing water harvesting.

Table 3. The strategic actions to solve riceland degradation

| The strategic adaptation                          | Number of respondents |
|--------------------------------------------------|-----------------------|
|                                                 | Has low productivity | Has high productivity |
|                                                 | Rarely implemented    | More often implemented |
| 1. Using certified seed                          | 18                    | 33                     | 127 |
| 2. Applying water efficiency                     | 37                    | 14                     | 95  |
| 3. Using water pump                              | 43                    | 8                      | 111 |
| 4. Implementing the minimum tillage system       | 10                    | 41                     | 7   | 122 |
| 5. Implementing organic fertilizer               | 41                    | 10                     | 100 |
| 6. Constructing water harvesting                 | 49                    | 2                      | 125 |
| 7. Recycling plant residue as organic fertilizer | 23                    | 28                     | 15  | 114 |
| 8. Giving a fallow season for riceland           | 19                    | 32                     | 11  | 118 |
It is essential to anticipate the rate of riceland degradation in Deli Serdang District. The low awareness from farmers, extension workers, researchers and government will make faster the rate of riceland degradation. Then, the continuing impact will endanger rice sufficiency for total number of populations which is continuously increased in the future. For anticipating the rate of riceland degradation, this study found some strategic actions implemented by farmers in the field, such as implementing the minimum tillage, using certified seed, giving a fallow season for riceland and recycling plant residue as organic fertilizer. The implementation of minimum tillage is one of technical conservation techniques that can reduce soil mechanical disturbance, which means avoiding the soil structure breakage. The minimum tillage can also reduce the soil erosion, surface run-off, and reduce numbers of labour for land cultivation specifically [19]. Using certified seed is one of strategic adaptations facing riceland degradation by planting the tolerant variety that can adapt with the stress-prone agroecosystem. Planting tolerant variety is expected share high productivity as well [20]. Then, giving a fallow season for riceland is believed can maintain the riceland fertility. It allows soil to reproduce soil nutrients for next cropping season. Last, recycling plant residue as organic fertilizer will give the nutrients back to the soil. This strategic action will enrich soil fertility [7].

4. Conclusions
Deli Serdang District has the stagnant rice productivity over the years. Using two approaches, field survey together with soil analysis and household-based survey, this study determined that the riceland degradation in the study area affected by nutrient availability (na factor), nutrient retention (nr factor), root condition (rc factor), and erosion hazard (eh factor). Based on household-based survey, most respondents agree that the riceland degradation affected by climate change, lack of organic fertilization implementation, the water scarcity and the excessive of chemical fertilization implementation. Some strategic actions that respondents have implemented to minimize the rate of riceland degradation are increasing access to the technological information, improving local irrigation facilities, improving the accuracy of flood and drought forecasting, implementing the minimum tillage, using tolerant certified seed, giving a fallow season for riceland, minimizing chemical fertilizer and recycling plant residue as organic fertilizer. Overall, this study suggests to perform the proper cultivation management practices that are easy to be implemented by farmers, such as Integrated Crop Management (ICM) and Climate Smart Agriculture (CSA) to achieve the sustainability of rice production in Deli Serdang District.

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