Sustainable shallot production achievement through analyzing the land suitability and introducing the proper agronomic cultivation practices in Samosir regency

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Abstract. Samosir Regency is one of the highest regencies of shallot producers in North Sumatera Province. Approximately 255 ha of its harvested area produces 1,976.8 tons or contributes 12.1% for provincial level. The increase of consumption and industrial demand push the regency government to raise shallot production. On the other side, the two critical information about land suitability and the agronomic cultivation practices for shallot were limited. Thus, this study was arranged to enhance sustainable shallot production through analyzing the land suitability and introducing the proper agronomic cultivation practices. The field survey and soil analysis were conducted to support the Geographical Information System (GIS) and Evaluation System of Land Suitability tools. The results show that about 47,789 ha (38.65%) of Samosir Regency is suitable for shallot grouped in S3 level (Low Suitable); with some limiting factors such as nutrient retention and nutrient retention availability, and erosion hazard. While about 75,839 ha (61.35%) of the rest area was grouped in N level (Not Suitable) means grouped as an unproductive area for shallot growth with some limiting factors such as root crop and erosion hazard. Some strategic actions to improve land quality are giving organic and chemical fertilizer, applying agricultural lime to stabilize soil pH, increasing Cation Exchange Capacity (CEC), and implementing conservation techniques on the steep area by building terrace. Also, information about the agronomic cultivation practices for shallot is explained to strengthen the strategy for sustainable shallot production achievement in Samosir Regency.

1. Introduction

Shallot (Allium ascalonicum L) is a horticultural commodity daily consumed at the household level in a fresh and processed product. Its demand continuously increased in line with the population growth and the need for the industrial sector. Thus, although Indonesia has high shallot production, it still cannot fulfill the requirements. At the national level, North Sumatera Province is on the top eight for total production in 2019 and supply approximately 18,072 t or 1.14% of total national production. The highest production of shallot came from Central Java, East Java, and West Nusa Tenggara Province by 481,890 t, 407,877 t, and 188,255 t, respectively [1]. Shallot was categorized as a seasonal agricultural product; thus, the need for out of season was fulfilled by import. This import has advantages to take care of its availability and to stabilize the market prices.
Due to the significant demand from domestic and international sectors, shallot has a high prospect in the future. Shallot cultivation can obtain some advantages. For instance, it has a short-term harvesting period and be managed efficiently by simple technology. The climatic condition also supports the cultivation. The harvested product is easy to sell because shallot is one agricultural product that cannot be substituted with other products. In North Sumatera Province, Samosir Regency has 233 ha of the harvested area and produces 1,500 t of shallot in 2019. This production supplies about 8.3% of total production at the provincial level after Karo, Simalungun, Dairi, and Humbang Hasundutan Regency [2].

Samosir Regency is known for its shallot production and characteristic. Total harvested of shallot production on Samosir Regency is spread on all districts. Simanindo and Pangururan Districts give the highest production among the other districts by 740 t and 423 t, respectively [3]. Shallot from Samosir Regency (local variety) has a specific characteristic that differs from other varieties, such as its flavor, taste, color, and size. Furthermore, Samosir’s shallot has a stable market price compare with other varieties.

Unfortunately, the total production of shallot from Samosir Regency has been declining for ten years. In 2009, the real harvested and production of shallot were 355 ha and 2,024 t, respectively [4]. Some problems affect this issue, such as declining soil fertility and low implementation of technology by farmers. This study was conducted with two primary purposes to identify the status of land suitability of Samosir Regency for shallot and to review the agronomic cultivation practices for shallot. The expected output from this study is to realize sustainable shallot production in Samosir Regency.

2. Methods

Samosir Regency is one of the regencies of North Sumatera Province, which lied in the highland area, with the elevation ranges from 900 to 2,150 m above sea level. It is located on 2°21′38″ – 2°49′48″ N and 98°24′00″ – 99°01′48″ E geographically. It has approximately 1,861.08 km², divided by 1,236.28 km² for land and 624.80 km² for the lake (figure 1). This regency has consisted of 9 districts, where Harian District is the most expansive district for total area, and Sitio-tio District is the narrowest one by 560.45 km² and 50.76 km², respectively [3].

This study collected primary and secondary data to obtain the objectives. The primary data was collected from a field survey and soil analysis. Some kinds of the primary data, such as slope, elevation, physical and chemical characteristics. While, data collection for the secondary data was obtained from the Statistical Institution of Samosir Regency to find the information about total production, productivity, total harvested area, administrative boundary, and climatic data (temperature and rainfall). Reviewing the literature of some research is performed to find the proper agronomic practices for shallot cultivation.

There were three main steps for this study. For the first step, a field survey was conducted to observe the study area and collect soil samples compositely on the previously marked location. There were 32 total soil samples collected based on the number of land units. A land unit means an area with a similar characteristic of soil parameter in the slope, elevation, and soil type. All soil samples were brought to the laboratory to analyze the pH, texture, P₂O₅, K₂O, C-org, and CEC (Cation Exchange Capacity). For the second step, the laboratory data and data from the field survey were entered into Evaluation System for Land Suitability or Sistem Penilaian Kesesuaian Lahan (SPKL) tool [5]. This tool has a specific purpose for generating the level of land suitability for shallot by four classes: highly suitable (S1), moderately suitable (S2), marginally suitable (S3), and unsuitable (N) [6]. All the outputs from land suitability classification were then transferred to ArcGIS to create a land suitability map for shallot in Samosir Regency. For the last step, some research and project articles related to shallot cultivation were reviewed and then summarized to finalize the proper agronomic cultivation practices.
3. Results and discussion

3.1. Land suitability for shallot

In terms of elevation, the study area is divided into five classes: 0 – 400 m above sea level, 400 – 700 m asl, 700 – 1,200 m asl, 1,200 – 2,000 m asl, and > 2000 m asl. Similar to elevation level, the study area also has diverse slope classification ranges from flat level (0 – 3%) to mountainous level (>45%). From field observation, it can be validated too that Samosir Regency has three soil types, Entisol, Inceptisol, and Histosol. In terms of climatic data, Samosir Regency is classified into the tropical wet climate with mean temperature ($T_{\text{mean}}$) is 17 – 29 °C. Throughout 2018, Onan Runggu Districts have the highest average rainfall in December by 537 mm and followed by Ronggur Nihuta District by 532 mm in October [3].

Based on data processing and analysis, there are eight land suitability classes for shallot in this study area. Its limiting factors differentiate this classification. Some limiting factors are nutrient retention (nr), nutrient availability (na), root condition (rc), and erosion hazard (eh). The detailed information about land suitability classification for shallot, including its limiting factors, is presented in Table 1.

| No | Land suitability class | Limiting factor (s) | Total area |
|----|------------------------|---------------------|------------|
| 1  | S3                     | Nutrient retention  | 677.13     | 0.55       |
| 2  | S3                     | Nutrient retention; Nutrient availability | 27,994.99 | 22.64      |
| 3  | S3                     | Nutrient retention; erosion hazard | 322.69   | 0.26       |
| 4  | S3                     | Nutrient retention; Nutrient availability; erosion hazard | 18,794.47 | 15.20      |
| 5  | N                      | Root condition      | 37,767.11  | 30.55      |
| 6  | N                      | Erosion hazard      | 18,225.74  | 14.74      |
| 7  | N                      | Root condition; erosion hazard | 12,905.80 | 10.44      |
| 8  | Others                 |                      | 6,940.83   | 5.61       |

**TOTAL** 123,628.76 100.00
Besides tabular data format, this study also presents the land suitability for shallot in a spatial format. This format helps the reader to identify easily where is the exact area for the particular class spatially. This spatial format generated by ArcGIS by transferring all output into polygon shapefiles is presented in figure 2.

![Figure 2. Land suitability map for shallot in Samosir Regency.](image)

By paying attention to the result of land suitability classification for shallot in tabular and spatial format, it can be recognized that Samosir Regency has low soil fertility. It can be noticed easily, and this regency has only S3 class, which means low suitable for shallot. There is no land in Somosir Regency categorized in S1 (Highly Suitable) and S2 classes (Moderately Suitable). Furthermore, the S3 type was covered mainly by the limiting factor of nutrient retention and nutrient availability. These limiting factors inform that land of Samosir Regency has a big problem at biological and chemical sites. Some variables that influence the value of nutrient retention and availability are CEC, Base Saturation, pH, C-org, N-total, P2O5, and K2O.

The low fertility of agricultural land in Samosir Regency is in line with the decreasing shallot production, particularly over ten years. Since 2009 there has been a decrease in total harvested areas and total production by 122 ha and 425 t. Some factors behind this problem found in the field are a high implementation of chemical fertilizer and chemical pesticides, poor organic fertilizer performance, burning harvested residue, agricultural land conversion, and low farmers' knowledge about agricultural technology.

Solving this problem needs integrative collaboration between local government, research institutions, financial institutions, private agencies, extension agencies, and farmers themselves as the main actors. Some strategy actions may improve agricultural land quality are giving organic fertilizer, applying agricultural lime to stabilize soil pH, increasing Cation Exchange Capacity (CEC), and doing conservation technique on the steep area by building terrace.

### 3.2. Agronomic practices for shallot cultivation

#### 3.2.1. Seedling treatment

In general, shallots are propagated by using tubers as seeds. The seed tuber quality determines the high and low shallot yield. The guaranteed-tubers must come from quite old age plants, about 70 – 80 days after planting. Bulbs for seeds preferably medium size (5 – 10 g). Seed
tubers must be fresh, healthy, pithy (solid and not wrinkled), and bright in color. The seed tubers are ready to be planted when they have been stored for 2-4 months after harvest, and the shoots have reached the end of the tuber [7]. The best way of storing the seed tubers is by keeping them in the special warehouse and ties on the top. The excellent quality tubers for seedlings should have two cloves of tubers for medium size, while the large seed tubers should have three cloves of tubers. Some shallot varieties introduced in Samosir Regency are Bima Brebes, Trisula, Maja, Ampenan, Keling, Maja Cipanas, Sumenep, Kuning, Timor, Lampung, Bull and Varieties Other Local [8]. The cultivated shallots around Toba Lake is a local variety and commonly call as Toba Shallots. These local shallots have an advantage, especially at the specific and unique aroma. When Toba shallots are planted in another place, then the flavor will be different [9]. Before planting, the dry outer skin of the seed tuber is cleaned, and give a special seed treatment by dipping it in Rhizobacteria solution [10]. For seed tubers whose shelf life is less than two months, usually cut the tip of the tuber approximately ¼ part of the whole tuber. This treatment aims to accelerate the growth of shoots and stimulate the growth of side tubers.

3.2.2. Soil tillage. The tillage is carried out to create soil conditions more fertile, and then it will support the shallot plants’ growth. This activity was done by cleaning the land from grass using herbicides 2-4 weeks before planting. There are four stages for this tillage: land raising, soil reversal, making beds and trenches, and overflowing. After these stages, the tillage is complete, and then the beds are rested for seven days, then the land is ready for shallot planting [11]. The shallots cultivation on acid soils (pH <6.0) requires liming using agricultural lime (dolomite). The recommendation of agricultural lime for soil with a pH <5.5 ranging from 1.5 – 2.0 t/ha, while on the ground with a pH <4 equal to 1-2 x Al-dd or adjusted for results soil analysis [12]. The agricultural lime was implemented during soil cultivation with an incubation period at least two weeks before the shallot seeds are planted.

3.2.3. Planting. The best time for shallot planting is at the end of the rainy season, commonly done in the morning to reduce evaporation. The first step of planting is making a hole with a 20cm x 20 cm [13]. If the soil conditions are too runny, then the bed is made higher to maintain conditions soil so that it is not too wet. During the rainy season on dry land, the shallot cultivation needs to use mulch, such as dry rice straw or silver, black plastic. Rice straw can maintain the stability of soil moisture by reducing water loss from the surface of the soil [14]. Plastic mulch is very effective for medium to high land use because it can prevent soil-borne diseases, decrease soil water loss and leaching of nutrients, and increase yields in the rainy season. The planting technique of shallots is by immersing the shallot into the hole that was previously made—immersed shallot until the tip has a similar level with the ground, three-quarters deep with part of the bud not covered with soil and facing upwards.

3.2.4. Watering. Shallot plants do not need water because the shallot root zone and tubers sensitive to water cause easy to rot, but the shallot plants need sufficient water [15]. Watering can be done twice a day in the morning before sunrise and evening or according to land conditions and weather in the field [16]. Watering the shallot plants according to the conditions of the growing season. During the rainy season, the frequency of watering is not often as in the dry season. In the dry season, watering is applied every day until the shallot plants grow. It is because, during the dry season, shallot plants require adequate watering. After the plants grow, the watering frequency is reduced every three days. Then, before harvesting time, watering frequency is progressively reduced. Besides, reducing the frequency of watering also aims to speed up the drying process.
3.2.5. Applying fertilizer. Dry land has low soil fertility generally, and it needs fertilizer and agricultural lime to increase land productivity. The organic and inorganic fertilizers are two-component inputs that give significant support for shallot growth. Compost or manure are examples of organic fertilizer which farmers commonly implement. The utilization of organic, natural, and biological fertilizers is an alternative method to address land degradation. As a result, intensive cultivation of shallots [17]. The essential fertilizers provided from mature organic fertilizers from manure (chicken, sheep, horse, or cow manure) by 10 – 20 t/ha or artificial organic fertilizer by 3 – 5 t/ha together with NPK (15-15-15) or NPK (16-16-16) by 500 kg/ha, and phosphate fertilizer (SP-36) by 100 – 150 kg/ha. This fertilization is applied 3 – 7 days before planting. The continuing fertilization is implemented at 10 – 15 days after planting; and then at the age of 30-35 days, 100 kg urea, 200 kg ZA, and 50-100 kg KCl/ha. The mixture of N and K fertilizers was applied in the afternoon inside the planting hole evenly, then watering until the fertilizer dissolves and gets into the soil (if there is no rain). The combination of N fertilization in urea and ZA to increase productivity also improves the quality of shallot in color and flavor.

3.2.6. Controlling pest and disease. The primary diseases and pests that attack shallot including Damping-off, Stemphylium blight, Downy Mildew, Basal Rot/Bottom rot, White rot, Onion smut, Black mold, Anthracnose/Twister/Seven curl disease, Pink root rot, Neck rot, Root-knot nematode, Thrips [18]. The prevention action to control pests and disease in shallot plants is by spraying pesticides periodically, as appropriate with planting conditions in the field. The pesticides or biopesticides used for controlling pests and diseases should prioritize effectiveness, efficiency, and right on the target with the correct dosage, including the hand sprayer used. This is important to avoid environmental pollution, waste, pest and disease resistance, and pesticide residues on plants to cause their problems [19].

3.2.7. Harvesting. Shallot mature in about four months after transplanting. Neck fall is an indication of maturity. Shallot for dry bulbs are ready for harvest when the bulbs are ripe, and 50 - 80% of the tops fall over [20]. Harvesting age in the rainy season is between 50 – 55 days, while in the drying season, 60 – 65 days. Shallots should be harvested during soil conditions dry and sunny to get a good quality tuber and avoid damaging the tuber. Harvested shallots are then tied to the stem for easy transport. Tubers for consumption, dried stems and leaves until quite dry (1 – 7 days), and avoid direct contact sunlight. The dry enough tubers are separated from the stems and the leaves, then grouped by size or quality tubers, then put in the mesh sacks to capacity 50 – 100 kg.

4. Conclusion
Shallot is one of the known horticultural commodities that came from Samosir Regency. It has promising market opportunity recently. Unfortunately, its total harvested area and production have been declining for ten years due to the high implementation of chemical fertilizer and pesticide and the low level of farmers’ knowledge about agricultural technology. Thus, it affects declining soil fertility, which can be observed from the status of land suitability for shallot in Samosir Regency. It has been detected that only the S3 (low suitable) class was determined for this study with the limiting factors. The limiting factors found majority covered by nutrient retention and nutrient availability means a big issue in soil chemical and biological fertility. Some essential strategies for farmers and local governments are giving more organic fertilizer, applying agricultural lime to stabilize soil pH and increasing Cation Exchange Capacity (CEC), and doing conservation techniques on the steep area by building terraces.

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