Identifying Land Resource Potency and Introducing New Varieties to Support Sustainable Maize Production in Simalungun Regency

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Abstract. As the third highest of harvested area for maize among regencies in North Sumatera Province, Simalungun Regency shares significant contribution for the total production. Unfortunately, there is a declining trend of production for five years influencing by total harvested area and productivity. These two factors are the justification to conduct this study with the aims to identify the potency of land resource for maize by measuring land-limitation factors and to introduce new varieties. Soil physic and chemical data were collected from field survey and laboratory analysis, and GIS and Evaluation System for Land Suitability tools were operated to detect the land potency. Meanwhile, Random Block Design with three replications performed to determine the well-adapted varieties. The results show that Simalungun Regency has 165,311 ha of high potency of land for maize and 238,834 ha and 26,952 ha has low and no potency of land, respectively. Nutrient retention and erosion hazard are the predominant limitation factors. Especially for adaptive-variety testing, this study found that Srikandi Kuning provides the highest productivity, 7.79 t/ha, that insignificantly difference with Bisma, Gumarang, Arjuna and Sukmaraga by 7.44, 7.27, 7.06 and 6.89 t/ha respectively. Conversely, Krisna has the lowest productivity, 4.98 t/ha, which is lower than provincial level. Applying land conservation measures and adopting new/tolerant variety be able to support sustainable maize production.

Keywords: land resources potency, maize variety, GIS, sustainable production, Simalungun.

1 Introduction

Maize (*Zea mays* L) is one of strategic agricultural commodities that commonly planted by farmers in Indonesia. Maize has many benefits, not only for food industry but also for chemical and textile industry, compost material, animal feed and ethanol fuel material [1]. Throughout the years, the increasing of maize demand occurred in line with population increase. According to the

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Ministry of Agriculture data in 2019, North Sumatera Province is included in the top ten of largest maize area, 292,388 ha, where East Java province is the top one by 1,276,792 ha [2]. The Provincial Statistical Institution reported that 168,158 ton of total production in North Sumatera Province was derived from Simalungun Regency, as the top three below Karo and Dairi Regency by 551,863 ton and 248,066 ton, respectively [3]. The statistical institution added that 56.5% of Gross Domestic Product of Simalungun Regency supported from agricultural sector [4].

For maize commodity, Simalungun Regency has 292,992 ha and 5,6 ton/ha for total area and productivity, respectively [3]. It spreads on the whole districts although with different level of total area which means natural resources supported the maize growth. Surprisingly, there were declining maize production in the last five years (2015 to 2019), from 3,435 t to 2,324 t [4], suspected to be mainly caused by decreasing total number of harvested area and productivity. Some major driving factors behind of these issues are agricultural conversion to urban or plantation area [5], land degradation caused by chemical fertilization and deforestation [6], drought and flood [7] and climate change [8]. These problems drive to worsening land fertility and lead to the declining of maize productivity.

Many researches have conducted to increase maize production which is focused on adaptation testing [9,10]. Especially for introducing new varieties, supporting of specific environment of physical and chemical of soil, temperature, slope and elevation is needed. When the land is categorized in highly suitable for maize, it must need some requirements, such as 20-26^{0}C for temperature, 42% for humidity, 5.8-7.8 for pH, less than 3% for slope, etc [11]. The sustainable evaluation in agricultural system needs soil quality as the main parameter, which is including physical, chemical and biological information [12]. Nutrient management is detected as contributing parameter of sustainable production as well [13]. Besides, information about land degradation on the particular sites also can be adopted to assess the land sustainability [14]. Furthermore, the lack availability of high-yielding varieites that has highly tolerant in the particular environment / condition influences the sustainability [15]. Unfortunately, lack of study related to support sustainable maize production by identifying land resources potency and introducing new varieties in Simalungun Regency.

In order to give some solution to farmers and policy makers, this study conduct field survey and field experiment. The field survey has a purpose to evaluate land resource potency for maize growth by considering climate, biophysical and chemical condition, such as temperature, slope, elevation and soil fertility. Meanwhile, field experiment which is focusing for adaptive-variety testing has a purpose to introduce and test which variety has well-adapted capacity and high productivity. The two objectives, to identify the potency of land resource for maize and to introduce eight new maize varieties, can achieved by doing these two methods. The expected results of this study are to maintain potential agricultural land and to meet the food needs, especially for maize.

2 Methodology

Simalungun Regency is located at 2^0 36' – 3^0 18' N and 98^0 32' – 99^0 35' E. It has 439,696 ha of total area and divided by 31 number of districts [4]. This regency is bordered by 7 regencies, Serdang Bedagai Regency, Deli Serdang, Karo, Toba Samosir, Asahan and Batubara Regency **(Figure 1)**. The elevation of Simalungun Regency ranges from 20 to 2,000 m above sea level and has diverse topography from flat to mountainous area. Thus, various crop especially maize can grow well in this area.

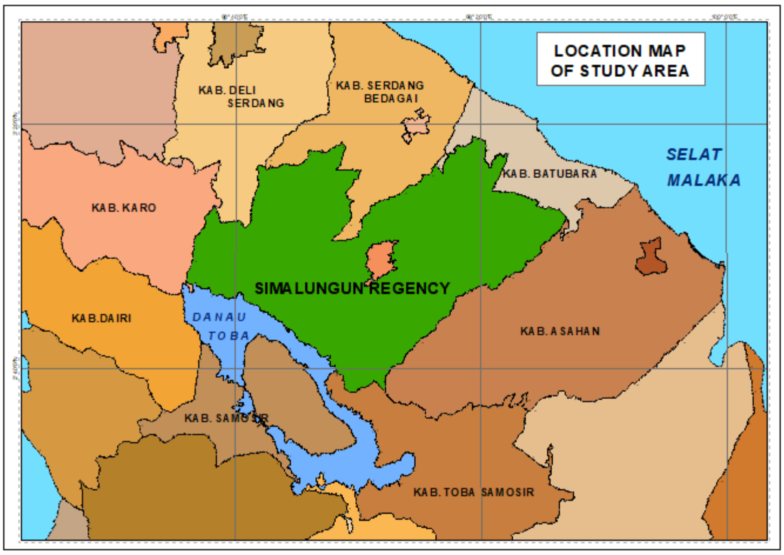

Fig. 1. Location map of sutdy area.

For achievieng the objectives, the primary and secondary data were collected to investigate the land resources potency and to identify well-adapted varieties in Simalungun Regency. The primary data were gathered through field survey, field research and soil analysis, while the secondary data, such as temperature, rainfall, soil type, maize production and productivity, administrative boundary and land use map, were collected from Statistical Institution of Simalungun Regency.

As the first procedure, field survey was conducted to collect soil samples. Total number of soil samples are depending on number of land mapping units on the study area, which have different characteristics related to the soil type, elevation and slope. All soil samples then brought to laboratory for being analyzed its physical and chemical soil characteristics (pH, texture, C-org, P_2O_5, K_2O, and Cation Exchange Capacity (CEC)). Then, the results of soil analysis together with soil type, slope, elevation and temperature data were used to measure its suitability level by doing suitability classification for maize with *Sistem Penilaian Kesesuaian Lahan* (SPKL) tool [16]. There are four categories, highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and unsuitable (N) [17]. As the last in this procedure was by mapping the land resources potency for maize through the output of suitability classification using ArcGIS tool.

Besides, this study conducted an experimental research to test eight new maize varieties (Anoman I, Arjuna, Bisma, Gumarang, Krisna, Srikandi Kuning, Srikandi Putih, and Sukmaraga) on the vegetative and generative of maize growth at Raya Bayu Village. The research design used Randomized Block Design (RBD) with three replications. Technical guidelines given by Ministry of Agriculture [18] was followed in cultivation management, starting from planting until harvesting step. The chemical fertilizers were implemented based on soil analysis, 350 kg/ha Urea, 200 kg/ha SP-36 and 75 kg/ha KCl. At the end, some parameters were measured including plant height, stem diameter, corncob length, corncob diameter, and production. The analysis of variance was used to determine whether there are any statistically differences between the means of parameters at 95% confidence level [19]. Then followed by Duncan's Multiple Range Test (DMRT) to measure specific difference between pairs of means [20].

3 Results

3.1 Land resource potency for Maize

Raw data of this study are collected from primary data, which is gathered from field survey and soil analysis, and secondary data. There are 5 soil orders in Simalungun Regency, Inceptisol, Entisol, Alfisol, Oxisol dan Ultisol. Information about soil order types was noted and would be input further into SPKL tool. Besides of soil types, some information about slope, elevation, temperature, humidity, condition of drainage system, texture, soil depth, soil fertility and erosion hazard levels were noted. Total area of this regency is distinguished by 113 land mapping units. Then, each information of land mapping unit inputted in SPKL as well (**Figure 2**).

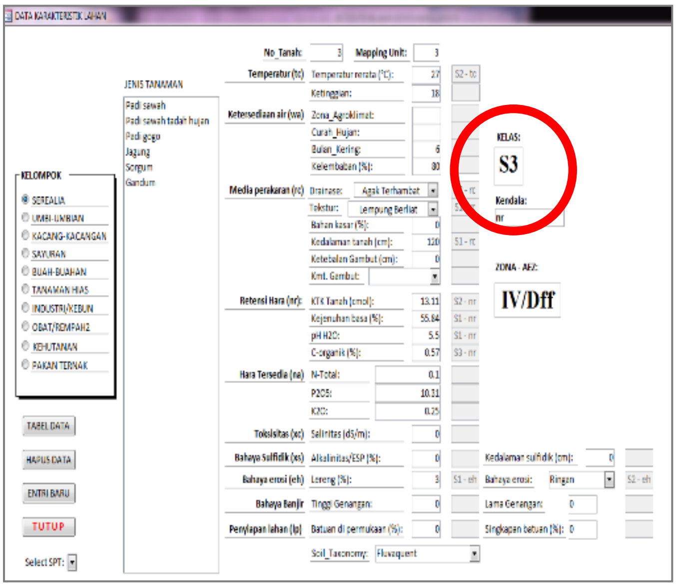

Fig. 2. Performance SPKL to point out the level of suitability classification.

Based on the collective result which is gathered from SPKL, Simalungun Regency has high land resource potency. The detailed potency of land resources is presented in Table 1. It informs that there are three classes of land suitability, moderately suitable (S2), marginally suitable (S3), unsuitable (N). There are some limited factors to support maize growth in moderately suitable class, temperature (tc), nutrient retention (nr), and erosion hazard (eh) by 165,311 ha (37.6%) of total area. Meanwhile, there are 238,834 ha of total area or more than 50% grouped in marginally suitable class. Temperature (tc), nutrient condition (nc), nutrient retention (nr) and erosion hazard (eh) are all the limited factors for this specific class. About 6% of total area Simalungun Regency (26,952 ha) is exist on unsuitable land for maize which is majority affected highly slope.

Table 1. Land suitability classification for maize in Simalungun Regency

Land Suitability Class	Limited Factors	Total area (Ha)	%
S2	nr	2,781	0.63
S2	tc,nr	108,083	24.58
S2	nr,eh	54,302	12.35
S2	tc,nr,eh	4,088	0.93

S3	rc	24,667	5.61
S3	nr	171,452	38.99
S3	eh	9,313	2.12
S3	rc,nr	14,336	3.26
S3	nr,eh	15,001	3.41
S3	rc,nr.eh	227	0.05
N	rc	51	0.01
N	eh	26,796	6.09
Lain-lain		8,599	1.96
Total		**439,696**	**100**

The spreading of potential land resource for maize is presented in **Figure 3**. By ignoring land uses, such as forest, plantation and urban, there are about 404,250 ha (91%) of total area grouped in highly potency for maize, which is derived by combining S2 and S3 classes.

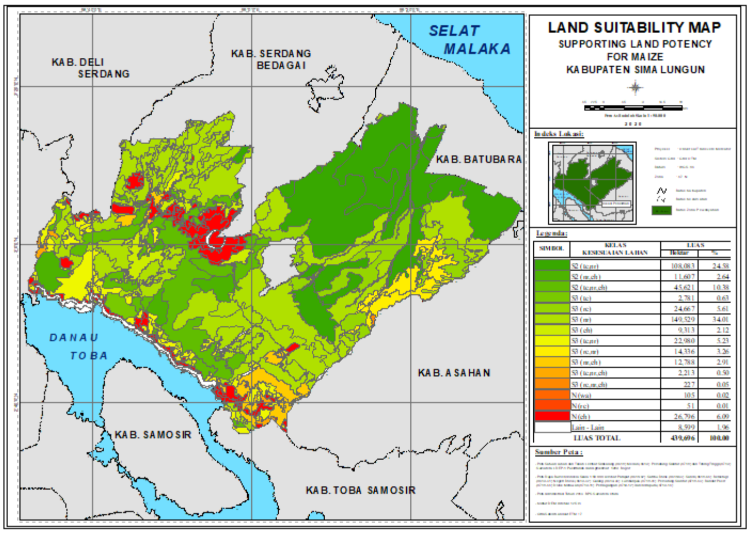

Fig. 3. Spatial distribution of land resource potency for maize.

3.2 Well-adapted new maize varieties

Based on descriptive data [21], all tested-varieties have 85 – 110 days of harvesting time. However, due to the location of experimental research took place on highland which has highly humidity, causing longer the harvesting time (120 – 130 days). The result shows that tested-maize varieties gave significant influence to four parameters, stem diameter, corncob diameter, and production statistically. Meanwhile, tested-maize varieties gave insignificant influence to the plant height and corncob length parameters (Table 2).

Table 2. Means of some vegetative and generative parameters of maize at some maize varieties on Simalungun Regency

Variety	Plant Height (cm)	Stem Diameter (cm)	Corncob Length (cm)	Corncob Diameter (cm)	Production (ton)
Anoman I	176 a	3,00 ab	17,36 a	4,75 b	6,63 b
Sukmaraga	219,26 a	3,05 ab	18,09 a	4,90 b	6,88 ab
Bisma	198,13 a	3,12 a	17,68 a	5,16 a	7,44 ab
Srikandi Kuning	195 a	2,86 ab	18,88 a	4,92 ab	7,79 a
Arjuna	199,93 a	2,94 ab	17,86 a	4,82 b	7,05 ab
Srikandi Putih	166,33 a	3,16 a	17,23 a	4,69 b	6,55 b
Gumarang	188,66 a	2,76 b	17,10 a	4,84 b	7,26 ab
Krisna	200,26 a	2,42 c	16,05 a	4,36 c	4,98 c

Note: In a column, means followed by a common letter are not significantly different ($P<0.05$) by DMRT

Table 2 informed that Sukmaraga and Srikandi Putih have the highest and the lowest of plant height by 219.26 cm and 166.33 cm, respectively. For the corncob length parameter, Srikandi Kuning and Krisna have the highest and the lowest level by 18,88 cm and 16.05 cm, respectively. The analysis of variance showed that both these parameters were insignificant difference statistically for all tested-varieties at 95% confidence level.

Srikandi Putih has the highest level of stem diameter, 3.16 cm, which is insignificant different statistically with Anoman I, Sukmaraga, Bisma, Srikandi Kuning and Arjuna, but significantly different with Gumarang and Krisna that have 2.76 cm and 2.42 cm, respectively at 95% confidence level by DMRT. For the parameter of corncob diameter, Bisma has the highest level and followed by Srikandi Kuning by 5.16 cm and 4.92 cm, respectively. It can be observed as well that this specific parameter was insignificant different for both varieties; while, Krisna has the lowest level of corncob diameter, 4.36 cm, and different significantly with all varieties.

For the last parameter, Srikandi Kuning has the highest production, 7.79 ton, and followed by Bisma, Gumarang, Arjuna, and Sukmaraga by 7.44, 7.26, 7.05 and 6.88 ton, respectively. This production parameter gives insignificantly different with the previous varieties. As shown by Table 2 that Krisna variety has the lowest level for all parameter, except at plant height parameter; and stem diameter, corncob diameter and production parameters give significantly different with all tested-varieties at 95% confidence level.

4 Discussion

By observing the output data from SPKL tool, there is no land on Simalungun Regency classified into highly suitable (S1) class for maize. It can be noticed that biological, chemical and physical soil fertility has been declining over years. It means land degradation has been occurring implicitly on this regency. Furthermore, Table 1 informed that nutrient retention (nr) is the major limited factor in land suitability classification, which is pH, C-org, base saturation, and CEC are the indicators for this specific limited factor.

Land degradation in Simalungun Regency majority caused by anthropogenic which is affected by human activities, through chemical fertilization practice, minimum organic fertilization usage, chemical pesticide practice, and burning harvested-residue. These farmers' measures drive to decrease soil fertility level. Thus, this study found there are only S2 and S3 suitability classes for maize in Simalungun Regency. Fortunately, this problem is not a big deal, since soil fertility can be improved by integrated crop and water management intensively. Some of measurements which is can be performed on farmers field, such as soil cultivation, organic fertilization, controlling the weed, pest and disease, organic pesticide, crop rotation, and reuse crop harvest residue. Concerning on the highly slope in Simalungun Regency, technical conservation on the steep slope is urgently needed. It will be useful to avoid loss of soil surface.

Especially for testing maize varieties, it can be concluded that Srikandi Kuning and Bisma are well-adapted varieties in Simalungun Regency. These varieties performed well especially in generative growth phase. They have insignificant different statistically for corncob diameter, corncob length and production. Through this achievement, Srikandi Kuning and Bisma varieties have to be socialized to the others farmers, local agricultural institution and policy makers as new well-adapted varieties in Simalungun Regency.

Due to lack of information about land resources potency in Simalungun Regency and new maize varieties testing in the field as well, this study is helpful as source information for farmers and local government. All information can be use as baseline data to generate a new policy to improve agricultural sector in Simalungun Regency specifically.

5 Conclusion

Declining maize production for the last five years in Simalungun Regency majority affected by decreasing of total area of maize and the stagnant productivity. By doing identification on land resource potency for maize, farmers and decision makers get a precious information to generate some strategic actions to increase maize production. Meanwhile, implementing experimental research on the field added farmers' insight about new well-adapted maize varieties and farmers' knowledge about integrated crop management especially for maize. Some new technical conservation will be able to generate by developing information from land suitability classification together with limited-factors as well.

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