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Exploration of the Potential of Local Cassava Genotypes to Support Food Security in the Highlands of Toba Regency

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Abstract

One of the cassava-producing districts in highland topography is Toba Regency, where cassava plantation centers spread across Laguboti District. Cassava land is starting to be displaced due to a lack of land management and processing. This study aims to enable the community to maximize cassava growth based on different genotypes and land use according to soil characteristics, thereby increasing cassava production as a food crop in Toba Regency, North Sumatra, Indonesia. The methods involved determination of land units, observations of morphological characteristics of cassava, observations of land characteristics, and collection and laboratory analysis of soil samples from cassava fields. The results revealed seven types of cassava diversity in Toba Regency with distinct morphological characters: Malaysia (G1), Siroti (G2), Simerah (G3), Sumedang (G4), Siputih (G5), Adira (G6), and UJ5 (G7). The distribution of pH and nutrient content in cassava fields with different genotypes in Laguboti District, Toba Regency, was highly varied: pH ranged from acidic to neutral, nitrogen from 0.17%–0.63%, phosphorus from 0.05%–0.24%, and potassium from 0.04%–0.27%. The altitude of the study sites ranged from 920–940 m asl.

INTRODUCTION

Cassava is a tropical root crop native to the Amazon region and a staple food for about 800 million people worldwide. *Cassava* (*Manihot esculenta* Crantz) is one of about 100 species of trees, shrubs, and herbs in the genus *Manihot*, distributed from northern Argentina to the southern United States. It took a long time for cassava to spread to other regions, especially Java. It is estimated that cassava was first introduced to the districts of East Java in 1852. Consumption increased rapidly in the early 20th century when it was used as a staple food instead of rice. Cultivation also became popular, and people were encouraged to expand cassava production. The increase in cassava cultivation coincided with rapid population growth in Java, as rice production lagged (FAO, 2013; Utama & Rukismono, 2018).

North Sumatra is one of Indonesia's main cassava production centers. This feedstock can be developed on dry and fallow land, especially in paddy fields where irrigation is limited and rice cultivation is not possible. The North Sumatra region is highly suitable for cassava due to its land typology and topography, which ranges from flat lowlands to hilly highlands. The largest cassava cultivation centers in North Sumatra are in Serdang Bedagai (364,512 tons), Simalungun (283,664 tons), Deli Serdang (143,815 tons), and Tobasa Mosir (28,600 tons) (Food Crops and Horticulture Sector, 2019). Cassava plants grow at altitudes of 700–1500 m above sea level but face low-temperature stress (Agricultural Extension Center, 2019).

One highland cassava-producing region is Toba Samosir Regency, now renamed Toba Regency. Most of Toba Regency's population depends on agriculture for their livelihood. Agriculture is a priority sector for Toba Regency to drive its economic transition in 2020. This sector contributes significantly to the regency's Gross Regional Domestic Product (GRDP), accounting for about 31.28% (Statistics of Toba Regency, 2021).

Food crop production in Toba Regency includes rice (paddy and upland fields), corn, cassava, sweet potatoes, peanuts, soybeans, and onions. Cassava is one of the key commodities. Cassava production in Toba Regency was 13,800.30 tons in 2019, 20,689 tons in 2020, and 32,439 tons in 2021 (Central Statistics Office, 2021). Cassava plantation centers are spread across Toba Regency, particularly in Laguboti District. This is evidenced by the largest tapioca flour processing factory in Laguboti District, namely PT. Hutahean (Simanjuntak, 2017). In 2018, cassava production in Laguboti Sub-district was 30.25 tons per hectare across 46 ha, totaling 1,858.29 tons spread across several villages (Statistic of Laguboti, 2019).

Toba highland cassava holds potential for agriculture, especially food crops developed in Indonesia (Diaguna et al., 2022). However, its production has not matched lowland cassava output. Currently, cassava lands face threats from overcrowding, real-world challenges, and limited public knowledge of land management, resulting in declining populations and quality (Hauser et al., 2014; Ezui, 2017). This is supported by the Toba Regency government statement (2019) that annual cassava production has declined due to reduced planted and harvested areas for raw materials.

Land factors are the main issue in cassava cultivation. Land characteristics—such as pH, organic carbon, available nutrients (nitrogen, phosphorus, and potassium), effective soil depth, coarse material, and texture—can affect plant productivity (Nurdin et al., 2021). Declining land productivity stems from nutrient depletion without balanced management. Soil conditions in Toba Samosir Regency are dominated by podzolic soils, covering 267,164 ha or about 75.89% of the total land area (Directorate General of Regional Infrastructure, 2020).

Therefore, this research explores the potential of local cassava genotypes to support food security in the highlands of Toba Regency by maximizing cassava growth through different genotypes and land use tailored to soil characteristics. It aims to boost cassava production as a food crop in Toba Regency and determine nutrient distribution patterns. The study enables communities to optimize cassava growth using diverse genotypes and soil-based land management, thereby improving production in Toba Regency, North Sumatra, Indonesia. Methods include determining land units, observing cassava morphological characteristics, analyzing land features, and conducting laboratory soil sample analysis. Benefits encompass enhanced local practices, higher yields via improved management, contributions to regional food security, insights into genotype-soil interactions for variety selection, and identification of optimal soil conditions for sustainable productivity.

METHODS

The research location was in Laguboti District, Toba Regency. Laguboti District is located at N 2° 13' – 2° 23' and E 98° 08' – 99° 15' with an altitude of 905-1,500 meters (Figure 1). Research sampling in the form of cassava and soil samples as well as coordinate points was carried out in October 2018, and nutrient analysis in the laboratory was carried out from November to December 2018. Nutrient distribution maps were made in August 2022.

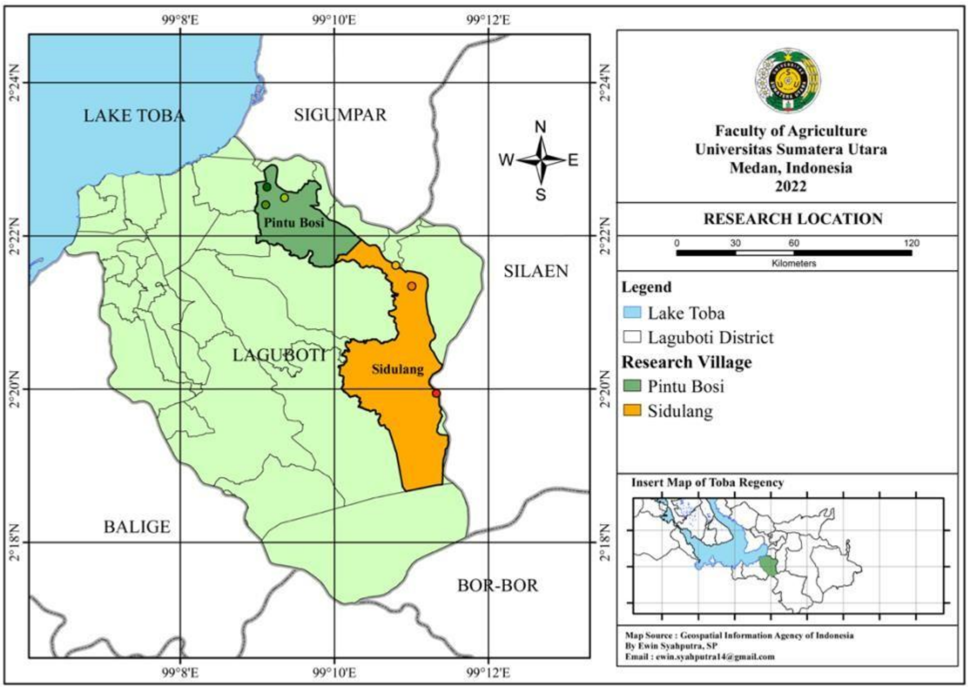

Figure 1. Map of Research Locations in Laguboti District, Toba Regency (N 2°13'–2°23' and E 98°08'–99°15')

The choice of research location was based on secondary data from Statistic of Toba regarding the presence of cassava plants around Toba Regency which was at an altitude of > 700 m above sea level. Based on secondary data by Toba Regency Statistics (2019), it is known that there are 21 villages in Laguboti District, but not all villages have cassava cultivation. Two villages with the largest cassava plantation area were selected in Laguboti District as the location for soil sampling. Selected villages with cassava commodities with the largest harvested area and production in Laguboti District, Toba Regency, that were Pintu Bosi Village (20 Ha of harvest area and 814,041 tons of plant production) and Sidulang Village (8 Ha of harvest area and 326,433 tons of plant production.

Table 1. Secondary Data on Harvest Area, Production, and Productivity of Cassava by Village in Toba Regency in 2018 with reference by Toba Regency Statistics (2019).

Village	Harvest Area (Ha)	Production (ton)	Average of Productivity (kw/Ha)
Pintu Bosi	20	814,041	407,02
Sidulang	8	326,433	408,04
Sintong Marnipi	8	322,926	403,65
Ujung Tanduk	5	197,445	394,89
Haunatas I	1	39,489	394,89
Haunatas II	1	39,489	394,89
Sibarani Nasampulu	1	39,489	394,89
Simatibung	1	39,489	394,89
Pardomuan Nauli	1	39,489	394,89
Gasaribu	-	-	-
Pasar Laguboti	-	-	-
Aruan	-	-	-
Lumban Bagasan	-	-	-
Tinggi Ni Pasir	-	-	-
Ompu Raja Hutapea	-	-	-
Sitoluama	-	-	-
Pardinggaran	-	-	-
Lumban Binanga	-	-	-
Siraja Gorat	-	-	-
OR. Hutapea Timur	-	-	-
Ompu Raja Hutalian	-	-	-
Total	46	1858,29	403,98

The method in this research is the determination of land units, observations of morphological characteristics of cassava, observations of land characteristics, and the collection and analysis of soil samples on cassava land carried out in the laboratory. The land unit map is an amalgamation of several types of maps, including soil type, land use, and slope, which then produces several similar parameters so that they can represent the characteristics of the land being sampled. Create a map of the land unit (Land Unit) using the ArcGIS 10.3 application (Figure 2).

A purposive sampling method was used in determining the location of soil sampling, selecting land with cassava based on the land unit that had been created, Toba Regency secondary data, and field surveys based on statements from local farmers. Overall, Laguboti District, North Toba Regency has 38 land units with different land characteristics (Table 2). This research was conducted in 2 villages. The first 3 sampling points were taken at Pintu Bosi Villageand the next 4 sample points were taken in Sidulang Village.

Morphological analysis was carried out on the types of cassava found in each research location. Then the soil samples were taken. At each sampling point, a minimum of 4 soil samples were taken which were composited to be homogeneous. Then by using GPS coordinates are recorded at each observation point of the soil samples taken. Soil samples were taken using a soil drill with a depth of 0-20 cm. Data analysis was carried out by collecting primary data obtained directly through research subjects including data obtained from laboratory analysis results, including pH, Nitrogen (%), Phosphorus (%), and Potassium (%) (Simple Science, 2025).

After knowing the results of nutrient analysis, a Value Distribution Map of the Characteristics of Nutrients on cassava fields with various genotypes was made using the ArcGIS 10.3 application. Open the ArcGIS 10.3 application, then enter the shapefile data in layers from the overlay map of soil type, land use, and slope, then enter the coordinates of the distribution point of data collection and laboratory analysis results which include nutrient characteristics, namely soil pH, Nitrogen (%), Phosphorus (%) and Potassium (%). The soil type map at the research site is shown.

Table 2. Land Unit Map Legend for Research Locations in Toba Regency

	Type of soil	Vegetation	Slope Class (%)
1 Inc-Hr-L1	Inceptisol	Jungle	0 – 8
2 Inc-Hr-L2	Inceptisol	Jungle	8 – 15
3 Inc-Hr-L3	Inceptisol	Jungle	15 – 25
4 Inc-Hr-L4	Inceptisol	Jungle	25 – 45
5 Inc-Hr-L5	Inceptisol	Jungle	>45
6 Inc-Pe-L1	Inceptisol	Plantation	0 – 8
7 Inc-Pe-L4	Inceptisol	Plantation	25 – 45
8 Inc-Ru-L1	Inceptisol	Perumahan	0 – 8
9 Inc-Sa-L1	Inceptisol	Ricefield	0 – 8
10 Inc-Sa-L2	Inceptisol	Ricefield	8 – 15
11 Inc-Sa-L3	Inceptisol	Ricefield	15 – 25
12 Inc-Sa-L4	Inceptisol	Ricefield	25 – 45
13 Inc-Sa-L5	Inceptisol	Ricefield	>45
14 Inc-Su-L1	Inceptisol	River Area	0 – 8
15 Inc-Te-L1	Inceptisol	Moor/Field	0 – 8
16 Inc-Te-L2	Inceptisol	Moor/Field	8 – 15
17 Inc-Te-L3	Inceptisol	Moor/Field	15 – 25
18 Inc-Te-L4	Inceptisol	Moor/Field	25 – 45
19 Inc-Te-L5	Inceptisol	Moor/Field	>45
20 Ult-Hr-L1	Ultisol	Jungle	0 – 8
21 Ult-Hr-L2	Ultisol	Jungle	8 – 15
22 Ult-Hr-L3	Ultisol	Jungle	15 – 25
23 Ult-Hr-L4	Ultisol	Jungle	25 – 45
24 Ult-Hr-L5	Ultisol	Jungle	>45
25 Ult-Ru-L1	Ultisol	Housing area	0 – 8
26 Ult-Ru-L2	Ultisol	Housing area	8 – 15
27 Ult-Ru-L4	Ultisol	Housing area	25 – 45
28 Ult-Sa-L1	Ultisol	Ricefield	0 – 8
29 Ult-Sa-L2	Ultisol	Ricefield	8 – 15
30 Ult-Sa-L3	Ultisol	Ricefield	15 – 25
31 Ult-Sa-L4	Ultisol	Ricefield	25 – 45
32 Ult-Sa-L5	Ultisol	Ricefield	>45

		Type of soil	Vegetation	Slope Class (%)
33	Ult-Se-L1	Ultisol	Bush	0 – 8
34	Ult-Te-L1	Ultisol	Moor/Field	0 – 8
35	Ult-Te-L2	Ultisol	Moor/Field	8 – 15
36	Ult-Te-L3	Ultisol	Moor/Field	15 – 25
37	Ult-Te-L4	Ultisol	Moor/Field	25 – 45
38	Ult-Te-L5	Ultisol	Moor/Field	>45

Table 4. The description of Land Units at the Research Site

Districts	Village	Coordinate point	Altitude (m asl)
Laguboti	Pintu bosi	N 2°22'38.2908" E 99°9'7.56"	920
Laguboti	Pintu bosi	N 2°22'24.1716" E 99°9'6.624"	928
Laguboti	Pintu bosi	N 2°22'29.8668" E 99°9'21.5172"	927
Laguboti	Sidulang	N 2°21'36.7236" E 99°10'47.9532"	943
Laguboti	Sidulang	N 2°21'36.7236" E 99°10'47.9532"	943
Laguboti	Sidulang	N 2°19'57.1368" E 99°11'22.3692"	948
Laguboti	Sidulang	N 2°21'20.556" E 99°11'0.3372"	949

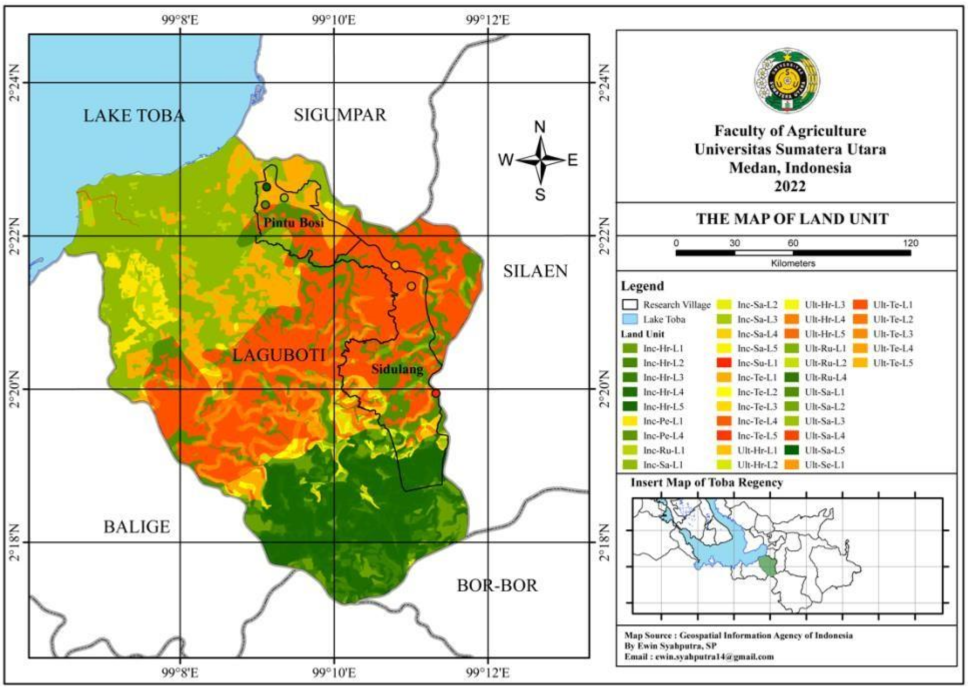

Figure 2. The Land Map Unit of Laguboti, Toba Regency

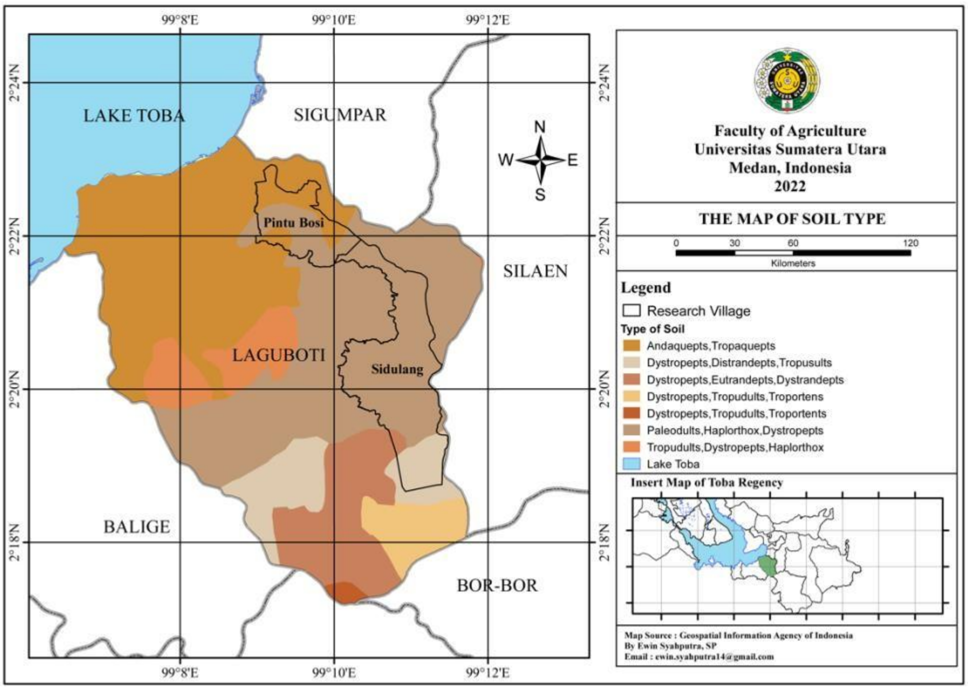

Figure 3. Map of Soil Types in Laguboti **District, Toba Regency**

RESULTS AND DISCUSSION

The Distribution of Soil Nutrient from Genotype of Cassava

The Laguboti district has seven cassava genotypes with different morphologies. Malaysian cassava is associated with (G1), Siroti (G2), Simerah (G3), Sumedang (G4), Siputih (G5), Adira (G6), and UJ5 (G7). The results of soil nutrient analysis on highland cassava land in Laguboti District, Toba Regency which include soil pH, N (%), P (%) and K (%).

Table 4. The analysis of soil nutrients in upland cassava land in Laguboti District, Toba Regency

Code	Types of cassava	Village	Altitude(m asl)	pH	N (%)	P (%)	K (%)
G1	Malaysia	Pintu bosi	920	5.5	0.63	0.24	0.11
G2	Siroti	Pintu bosi	928	6.2	0.40	0.17	0.04
G3	Simerah	Pintu bosi	927	6.3	0.17	0.06	0.24
G4	Sumedang	Sidulang	943	6.6	0.24	0.06	0.23
G5	Siputih	Sidulang	943	6.6	0.24	0.06	0.23
G6	Adira	Sidulang	948	5.1	0.20	0.05	0.27
G7	UJ5	Sidulang	949	5.4	0.26	0.08	0.26

Malaysia (G1) found in Pintu Bosi Village with an altitude of 920 m asl has a soil pH of 5.5 (acidic), 0.63% N (high), 0.24% P (very high), 0.11% K (moderate). Siroti (G2) in Pintu Bosi Village with an altitude of 928 m asl has a soil pH of 6.2 (slightly acidic), 0.40% N (moderate), 0.17% P (very high), 0.04% K (low). Simerah (G3) in Pintu Bosi Village with analtitude of 927 m asl has a soil pH of 6.3 (slightly acidic), 0.17% N (low), 0.06% P (low), 0.24% K (very high).

Sumedang (G4) in Sidulang Village with an altitude of 943 m asl has a soil pH of 6.6 (neutral), 0.24% N (medium), 0.06% P (low), 0.23% K (very high). Siputih (G5) in Sidulang Village with an altitude of 943 m asl has a soil pH of 6.6 (neutral), 0.24% N(medium), 0.06% P (low), 0.23% K (very high). Adira (G6) in Sidulang Village with an altitude of 948 m asl has a soil pH of 5.1 (acidic), 0.20% N (low), 0.05% P (low), 0.27% K (very high). UJ5 (G7) located in Sidulang Village with an altitude of 949 m asl has a soil pH of 5.4 (acidic), 0.26% N (moderate), 0.08% P (high), 0.26% K (very high).

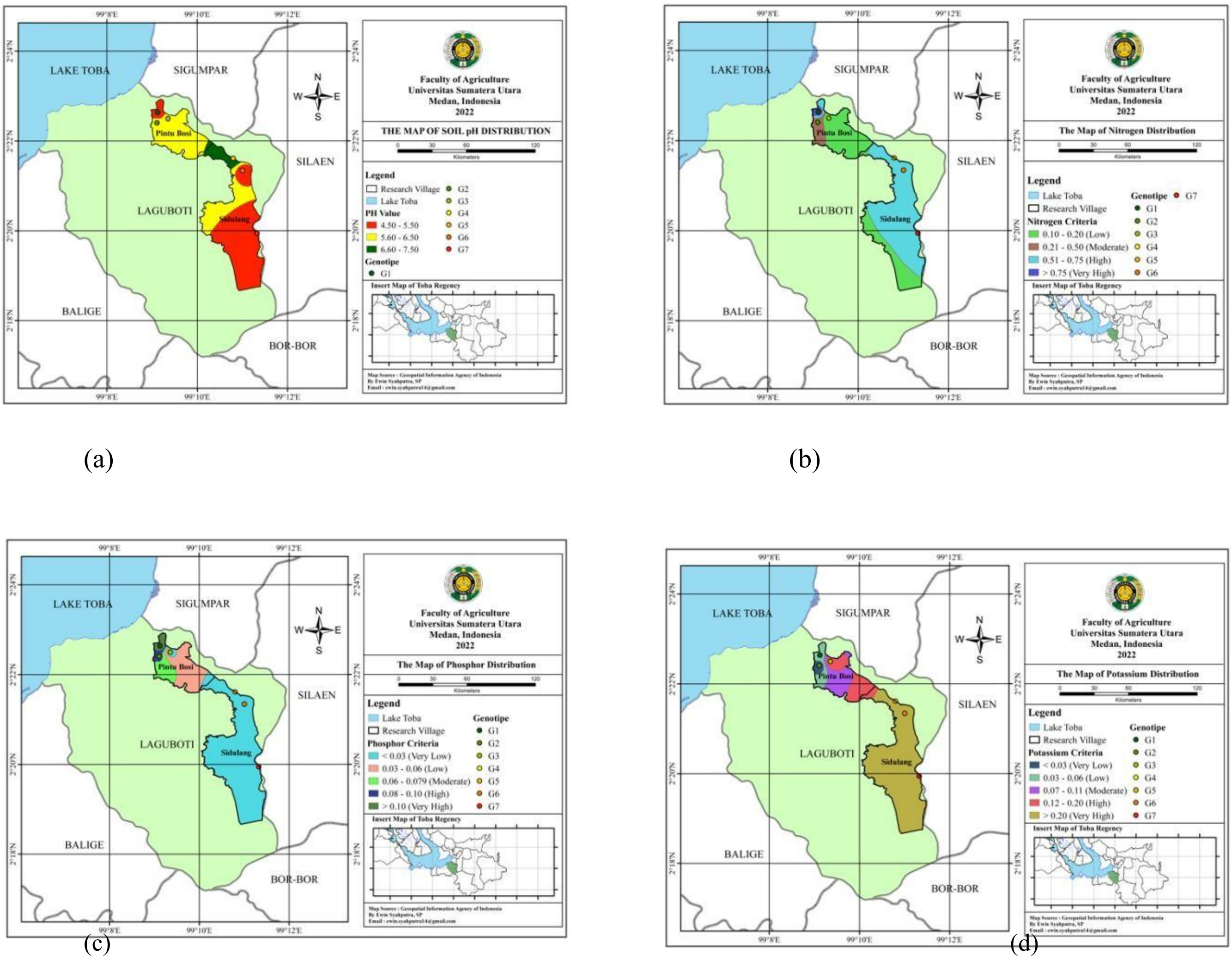

Figure 4. The map of diversity soil distribution in several genotypes of highland cassava in Toba Regency: (a) pH soil, (b) Nitrogen, (c)Phosphorus, and (d) Potassium.

Based on the soil type map (Figure 3), it is known that the soil orders at the research site are Ultisols and Inceptisols, sothe soil pH tends to be in the acidic and slightly acidic category, but for cassava species G4 and G5 the soil pH is neutral. Soil type will affect fertility, soil depth, and soil acidity. According to Harahap et al (2021), Soil pH also affects the solubilityof Al and Fe in the soil. The solubility of Al and Fe will be high in acid soils, resulting in abnormal plant growth due to theinappropriateness of very low pH conditions, resulting in poisoning by Al and Fe and decreasing the solubility of some elements. The distribution map of soil nutrient (pH, N, P and K) for several genotypes of highland cassava in Toba Regencyis shown in Figure 4.

Nitrogen levels in cassava fields in Laguboti District, Toba Regency ranged from 0.17% - 0.63%. The highest nitrogen content was found on land planted with Malaysian cassava (G1) in Pintu Bosi Village, which was 0.63%, while the lowest nitrogen content in Simerah cassava (G3) in Pintu Bosi Village was 0.17%. This low nitrogen nutrient can be caused by theloss of element N and the level of soil acidity, according to the statement of Nariratih et al. (2013) which stated that becauseN in the soil is very mobile, the presence of nitrogen in the soil can change or even disappear. The increase in the total N content in the soil is inversely proportional to the soil pH, the total N content in certain situations may become unavailable due to fixation and attachment, and the nature of its availability is determined by the changes that occur (Firmansyah and Sumarni, 2013).

Phosphorus levels in cassava fields in Ragboti district, Toba prefecture ranged from 0.05% to 0.24%. The land planted with Malaysian cassava (G1) in Pintu Bosi village has the highest phosphorus content of 0.24%, while the land planted withAdira cassava (G6) in Siduran village has the lowest phosphorus content of 0.24%. 0.05%. Phosphate levels fall into the lowto very high category. Cassava fields planted with Simerah (G3), Sumedang (G4), Siputih (G5), and Adira (G6) seeds havelow phosphorus levels. This is because the soil type at that location is Ultisol. Ultisol is rich in Al metal that can bind phosphorus to P-Al. This results in lower P nutrient content. According to Firnia (2018), P binds to Al and Fe in acidic soils.Aluminum ions were found to bind (fix) the P element in great abundance, making it difficult for plants to absorb P.

Potassium levels in cassava fields in Laguboti District, Toba Regency ranged from 0.04% – 0.27%. The highest Potassium level was found on land planted with Adira cassava (G6) in Sidulang Village, namely 0.27%, while the lowest Potassium level was on Siroti cassava (G2) land in Pintu Bosi Village, namely 0.04%. The adequacy of K nutrients greatly determines plant growth and the quantity and quality of cassava yields, because K is involved in various physiological processes, including cell growth, stomata opening, carbohydrate formation and translocation, protein formation, and phenolic compounds that can increase plant resistance to disease. The management of K nutrients in cassava in acid-dry landneeds to receive great attention (Subandi, 2014).

CONCLUSSION

In Toba Regency's Laguboti District, seven cassava genotypes—Malaysia (G1), Siroti (G2), Simerah (G3), Sumedang (G4), Siputih (G5), Adira (G6), and UJ5 (G7)—exhibit distinct morphological characteristics at altitudes of 920–940 m asl, with highly variable soil conditions across fields including pH from acid to neutral, nitrogen (0.17%–0.63%), phosphorus (0.05%–0.24%), and potassium (0.04%–0.27%). For future research, field trials should evaluate genotype-specific yield responses and nutrient uptake efficiencies under these varying soil profiles to identify optimal varieties for highland food security and develop tailored fertilization strategies.

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