Bulgarian Journal of Agricultural Science, 31 (No 3) 2025, 469–474

Evaluation of dryland agricultural soil chemical quality in Haharu district, East Sumba regency

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Abstract

Jawang, U. P., Linda, A. M., Nganji, M. U., Killa, Y. M., Lewu, L. D., Ndapamuri, M. H. & Kapoe, S. K. K. L. (2025). Evaluation of dryland agricultural soil chemical quality in Haharu district, East Sumba Regency. *Bulg. J. Agric. Sci., 31*(3), 469–475

Limited information on soil quality on dry land has resulted in efforts to increase agricultural land productivity not going well. The purpose of obtaining data and information on the status of soil chemical quality and directions for dryland agricultural development. The research methods used were survey method and land evaluation with lowery soil quality approach. The results obtained soil chemical values with a pH of 6.2–7.2, C-organic 0.44–5.35, N-total 0.04–0.88, P-total 6.19–138.92, K-total 8.22–103.94, CEC 22.31–40.72. Status of unhealthy soil quality at locations WUN1, RAM1, MBA2, unhealthy at locations NAP3, NAP4, PRA1, WUN2, and healthy soil at locations KAL1, KAL2, KAL3, NAP1, NAP2, KAD1, KAD2, WUN3, PRA1, MBA1, MBA2, MBA3, PRA3, PRA4, PRA5. Directions for improving limiting factors in locations with unhealthy and unhealthy soil categories by adding organic matter and site-specific balanced fertilization by utilizing site-specific organic matter.

Keywords: dry land agriculture; soil quality; soil chemistry; Haharu District

Introduction

Currently, dryland agriculture is developing very slowly. Some of the inhibiting factors include the lack of information related to land resources, inadequate access to science and technology, a lack of dry land technology innovation, and the limited knowledge of farmers about new technologies. The potential for dryland is emphasized in the land area for plant cultivation. However, it also has major limitations in terms of the insufficient availability of groundwater for plant growth and development. As a result, crop productivity is not optimal. According to Martunis et al. (2016), dryland is land that cannot be flooded for a certain amount of time in a year or land that can only be cultivated when it rains. The geographical location of each dry land in each region has different land characteristics, for instance, soil type, land use, land slope, rainfall, temperature, and the social economy of the community, which results in different land management techniques.

Important information in agricultural development plans on dry land is the ability of land resources so that land management is in accordance with land capabilities and the needs or requirements for growing cultivated plants. Land information data helps in determining agricultural systems on dry land such as planting time, suitable crop types, cultivation systems, innovations that need to be implemented and site-specific agricultural management for agricultural sustainability.

Assessment of the sustainability of land resources has developed where the function of the land is viewed holistically, not only on increasing agricultural productivity but on other uses. One indicator of land resource assessment is soil quality. Martunis et al. (2016) stated that soil quality is a description of the characteristics, physical, chemical and biological properties of the soil in support of its designation. Soil properties that are very responsive to environmental changes and the use of chemicals are soil chemical elements. Soil chemical properties are a description of soil characteristics regarding the solubility and availability of elements in the soil. Soil chemical reactions are processes that occur in the soil in providing nutrients and toxic elements for plant growth and development (Putri et al., 2019). Thus, identification of soil chemical elements is able to provide information on toxicity or nutrient contaminants.

Haharu District is the administrative area of East Sumba Regency. This area is located in the North West northwest part. It has a fairly large agricultural land and is one of the sub-districts with low agricultural productivity. One of the main limiting factors is that it has low rainfall characteristics (500–1200 mm/year), even though it is not evenly distributed every year. Agricultural development in this region still applies subsistence agriculture. One of the factors is the lack of information data related to land resources and the limited direction of land management.

The fulfillment of information related to the soil chemical resources of agricultural land in Haharu District was carried out using land survey and evaluation methods. The information will serve as a description of the chemical quality of the soil in Haharu District, East Sumba Regency, as well as a guide to chemical-based management on dry land.

Method

The research setting is Haharu District, East Sumba Regency. The research started in September 2019 – September 2020. Laboratory analysis was carried out at the Soil Chemistry Laboratory, Nusa Cendana University.

Research instruments include GPS, hoes, machetes, cameras, plastic bags, stationery, and soil testing equipment in the laboratory. The research material used composite soil and laboratory soil test materials.

This research applies descriptive exploratory methods, namely field survey methods and laboratory tests. Determination of the location of observations was carried out by purposive sampling based on map overlays (administration, land use, land slope, and soil type). The observed soil chemical parameters included pH, C-Organic, N-Total, P-Total, K-Total and Cation Exchange Capacity (CEC). Assessment of soil chemical quality in dry land in Haharu District using the lowery scoring method (Widiastuti et al., 2016) (Table 1).

Table 1. Soil quality scoring values and criteria

Scoring Values	Soil Quality Criteria
2.8–4.0	Healthy
1.5–2.7	Unhealthy
0.0–1.4	Not healthy

Results and Discussion

This section provides clear and concise descriptions and illustrations of research results, using tables, figures, and graphs (if necessary). This section also describes research findings or offers relevant scientific contributions to the field of study being researched. All tables, figures, and the like should be numbered sequentially and centered on the page.

Overview of research sites

Geographically, Haharu District is located at 9°20′37.8″S 119°51′53.1″E and 9°36′14.8″S 120°05′49.8″E Southern Sumba Island. The administrative area is 88.090 ha with a hilly topography. Geographical location determines the character of the climate, which is very extreme with very low rainfall (500–1200 mm/year) and even uneven rainfall every year. Soil is formed from the parent material of lime and coral, which results in high potassium content. The average solum depth is 20–30 cm where solum depth > 30 is somewhat limited.

Soil chemical quality

Soil reaction (pH)

Soil pH status is an indicator of the reaction of free hydrogen ions in soil solution and adsorbed on soil colloids. The state of soil pH can provide an overview of the chemical reaction of the soil or the nutrients available in the soil for plants. Basuki & Husin (2018) stated that soil pH is an implication of nutrient composition and availability and the emergence of toxic elements for plants.

Based on Table 2, agricultural land in Haharu District has a pH status from slightly acidic to neutral with pH values ranging from 5.7 to 7.2. The pH range shows that the soil quality in the area is very supportive of plant growth and soil ecology. Factors causing the increase were influenced by plant vegetation, low rainfall, cultivated plants, solum depth, and soil parent material. Prabowo & Subantoro (2017) argued that increasing soil pH is influenced by vegetation, parent material, land use, texture, rainfall and organic matter.

The pH range of agricultural soil in Haharu District is 5.7–7.2 so that the soil quality ranges from unhealthy to healthy. Thus, the average soil quality category is healthy soil. A pH value in the near-neutral category indicates an improvement in soil quality (Sakti et al., 2011). Healthy soil quality index shows the ease of nutrients that can be absorbed by plants and the activity of soil microorganisms goes well so that the nutrient cycle can take place well.

C-organic

Table 2 shows that the C-Organic content varies greatly from very low, low, medium, high and very high with a percentage value of 0.44–5.35. C-organic status varies so the quality is based on Lowery's scoring of unhealthy, less healthy and healthy. In this case, the average quality is less healthy. Siregar (2017) stated that an increase in soil C-Organic can affect the soil quality index which if the C-organic is high, the soil quality index is high and vice versa. Organic matter has a role in the physical, chemical and biological characteristics of the soil with the availability of nutrients and energy sources of microorganisms.

Various organic C-contents are influenced by the behavior of farmers in managing litter or crop residues of cultivated plants. Variation of C-organic soil is influenced by several factors including vegetation, solum depth, topography, climate and soil type. The vegetation of agricultural land in Haharu District is upland rice, corn, peanuts and seasonal crops. The average depth to the soil solum is 0–50 cm because it is influenced by the dominant sedimentary rock. Rainfall in this location is low at 500–1200 mm/year with an average of 3–4 wet months per year, namely December-March (Tim Lapangan ICRAF-IRED, 2016). According to Dwiastuti et al. (2016) explained that climate affects the organic matter content of the soil because it can accelerate or inhibit the decomposition process in the soil. The type of land use and the shape of the land affect the availability of organic matter as well as the collection and leaching of organic matter. Juarti (2016) stated that the type of land use could affect the C-organic content, the quality of soil biological activity, and land management.

N-total

Nitrogen is one of the chemical elements of the soil that determines the quality of the soil in supporting plant growth with the function of synthesizing amino acids and proteins. According to Siregar (2017), the value of N-Total has a close relationship with the value of soil quality. When the N-total value increases, the soil quality index increases and vice versa.

Table 2. Soil chemical characteristics of agricultural land in Haharu District

Sample location	pH	C-organic	N-total	P-total	K-total	CEC Cmol(+)/kg
		%		mg/100g		
KAL1	6.5	5.01	0.83	131.60	98.69	40.72
WUN1	6.2	1.27	0.19	28.84	24.71	24.41
NAP1	6.5	2.92	0.47	73.75	57.05	32.00
KAD1	6.7	3.89	0.63	98.63	75.03	35.86
WUN2	5.7	1.79	0.29	45.69	36.96	28.46
PRA1	7.2	1.65	0.25	38.22	31.41	25.63
KAD2	6.7	3.31	0.57	90.03	68.71	35.86
WUN3	6.3	3.86	0.65	102.56	77.70	37.37
PRA2	6.2	2.23	0.37	58.70	46.33	30.70
MBA1	6.4	4.94	0.84	133.43	99.93	40.54
MBA2	6.6	2.80	0.43	67.81	52.75	30.28
KAL2	6.8	3.83	0.61	95.94	73.06	35.17
RAM1	6.9	1.02	0.14	20.99	19.03	22.21
MBA2	7.2	0.44	0.04	6.19	8.22	20.76
KAL3	6.8	3.63	0.61	95.71	72.92	36.15
MBA3	6.5	2.66	0.42	65.67	51.13	30.33
NAP2	6.5	4.53	0.74	116.96	88.10	39.05
PRA3	7.2	4.16	0.68	108.00	81.74	37.74
NAP3	7.0	1.25	0.18	28.00	24.17	34.02
PRA4	6.9	5.35	0.88	138.92	103.94	32.68
PRA5	6.5	2.24	0.38	59.30	46.67	30.90
NAP4	6.9	1.39	0.19	30.01	25.53	23.48

Information: KAL = Kalamba, WUN = Wunga, NAP = Napu, KAD = Kadahang, PRA = Praibakul, MBA = Mbatapuhu, RAM = Rambangaru.

Source: Soil Laboratory Test Results, Faculty of Agriculture, UNDANA Kupang

The N-Total status of agricultural land in Haharu District varied from very low, low, medium and high, with a value range of 0.04-0.88%. The variation of N-total soil indicates that the soil quality is less healthy. The N-total is less because the value of organic matter is less healthy. Thus, the activity of soil microorganisms does not work well because of the limited energy from organic matter. The element N is produced from the decomposition of organic matter so that the availability of microorganisms in binding N is converted into amino acids and into nutrients in the form of protein by plants. The composition of plant tissue contains nitrogen, which is decomposed by soil microorganisms so that it is available to plants. Rahmah et al. (2014) suggested that the availability of nitrogen in the soil is influenced by the amount of organic matter and microorganisms in the soil. In this case, the composition of plant tissue contains large amounts of nitrogen, which can be decomposed by microorganisms into nitrogen that is available to plants. According to Siregar (2017), organic C has a positive effect on total N availability and soil respiration (CO_2). The element of N in the soil affects plant growth and protein supply.

P-total

Phosphorus is one of the chemical elements of the soil that determines the soil quality index and supports plant metabolic processes. Pinatih et al. (2015) stated that phosphorus, the chemical element in the soil, is needed by plants in large quantities and cannot be replaced by other nutrients.

The distribution of total soil phosphorus content in Haharu District is very diverse, ranging from very low, low, medium and high with values ranging from 6.19 to 138.93 mg/100 g. Based on Table 2, the total P quality of the soil varied from unhealthy, less healthy and healthy. The average value of total soil phosphorus on agricultural land is in the healthy category with a soil quality score of 3.27. The increase in the P value of the soil is influenced by intensive land use. Agriculture in Haharu is carried out by planting seasonal crops such as corn, upland rice, and peanut plants, using organic fertilizers, and without washing because of limited rainfall. Rahmah et al. (2014) suggested that the use of land with seasonal crops and the use of artificial fertilizers had an effect on the increase in phosphorus in the soil.

The availability of phosphorus in the soil is influenced by various factors, including organic matter, land use, tillage, and soil parent material. According to Firnia (2018), the availability of P in the soil is influenced by the nature and characteristics of the soil and soil management. Soil P content is also determined by the amount of P-containing minerals and their weathering.

K-total

Potassium is a soil chemical element that plays a very important role in the quality status of agricultural land in supporting plant growth and development because potassium is a macro nutrient needed by plants in the form of K+ ions.

The value of soil potassium in agricultural land in Haharu District is very diverse, ranging from very low, low, medium, high, and very high. The diversity of potassium values is influenced by land use, plant species, solum depth, and soil types and properties. Because the potassium value of the soil varies from 8.22 to 103.94 mg/100 g, the quality of the soil also varies between unhealthy, less healthy, and healthy. Based on the category of the number of soil samples, land with a high K value was categorized as healthy soil. Based on LIIRED (2016), in the Haharu area, the soil is formed from lime parent material, so the potassium value is high. Gunawan et al. (2019) stated that the level of soil potassium was influenced by soil parent material and soil pH.

Cation exchange capacity

Cation Exchange Capacity is a chemical property of soil that is closely related to soil quality and soil fertility, CEC describes cations that can be exchanged and absorbed by plants. Soil with high CEC content will have high soil quality and vice versa. Rahmah et al. (2014) states that the cation exchange capacity explains the amount of positive charge of cations that can be absorbed by soil colloids at a certain pH.

Agricultural land in Haharu District has various CEC values. Based on Table 2, the CEC value is in the range of 20.76–40.72, so the CEC status of the land is in the medium, high, and very high categories. The soil quality of the CEC was categorized based on the lowery score of less healthy and healthy. The diversity of CEC values is influenced by the amount of clay, content, and composition of organic matter in the soil. The high CEC in the area is caused by low rainfall and the types of cultivated plants, such as corn, long beans, and plant litter that are returned to the land so that the organic matter is high. Neswati et al. (2019) explained that the value of soil CEC is influenced by soil properties and characteristics, namely soil pH, texture or amount of clay, types of clay minerals, and organic matter.

Soil chemical quality status and management directions

Assessment of the chemical quality status of agricultural soils in Haharu District is the result of a combination of soil chemical parameters (pH, C-organic, N, P, and K, and CEC), which is less healthy with limiting factors for the quality of C-organic, nitrogen, phosphorus, and potassium. C-organic (WUN1, WUN2, PRA1, RAM1, MBA2, NAP3, NAP4), nitrogen (WUN1, RAM1, MBA2, NAP3, NAP4) phosphorus (RAM1, MBA2), and potassium (RAM1, MBA2).

The factors that influence the low and high quality of soil chemistry are low rainfall (0–850 mm/year), land slope, land use type (protective trees), land management (litter), vegetation, and solum depth. The location has unhealthy levels of C-organic, nitrogen, phosphorus, and potassium. It requires the addition of organic matter and limited elements by restoring cultivated plant litter and single fertilization or combination fertilizers. Management of plant litter in addition to organic matter and utilization of legumes (beans) is carried out so that the nitrogen nitrification process can run smoothly and increase phosphorus, potassium, and cation exchange capacity. Cahyadewi et al. (2016) explained that improving the use of fertilizers in a precise and site-specific manner is a technique for improving soil chemical quality. Utilization of local wisdom in the management of organic matter is carried out by using manure (Mulyani & Mamat, 2019). Haharu District has a large cattle field where every farmer has livestock. Rezig et al. (2012). A good combination of organic matter from organic waste and inorganic fertilizer is a good practice for maintaining poor soil fertility.

Conclusion

Chemical characteristics of agricultural land in Haharu District are pH ranges from slightly neutral to neutral with a range of values of 6.2–7.2, C-Organic is very low, low, medium, high and very high (0.44-5.35); N-Total with very low, low, medium, high and very high status (0.04-0.88); P-Total with very low, low, medium, high and very high status (6.19–138.92); K-Total with very low, low, medium, high and very high status (8.22-103.94); and CEC with medium, high and very high soil status (22.31-40.72).

Soil quality status is based on lowery scores at each sample location, namely unhealthy in samples WUN1, RAM1, MBA2; less healthy in samples NAP3, NAP4, PRA1, WUN2; and healthy in samples KAL1, KAL2, KAL3, NAP1, NAP2, KAD1, KAD2, WUN3, PRA1, MBA1, MBA2, MBA3, PRA3, PRA4, PRA5.

Directions for sustainable agricultural development can be implemented by improving the limiting factors on soils with unhealthy quality, namely by adding organic matter and balanced and site-specific fertilization by utilizing site-specific organic materials.

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Received: **March, 05, 2024**; *Approved*: **May, 17, 2024;** *Published:* **June, 2025**