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Visual Soil Quality Assessment of Rice Production Areas in Datu Piang, Maguindanao del Sur

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Abstract- This study assessed the soil quality of selected rice farms in Barangay Montay, Datu Piang, Maguindanao del Sur, using the LADA Visual Soil Assessment (VSA) manual. Thirty samples from ten sites were evaluated based on soil structure, surface crusting, earthworm abundance, plant root development, and soil texture. The visual scores were integrated to determine the Soil Quality Index (SQI). The results revealed variations in soil conditions among the sites. Several samples exhibited favorable soil structure, while others showed firm clods and evidence of tillage pans. Most samples exhibited moderate soil crusting, while earthworm abundance was generally low. Sandy, sandy loam, and silt loam were the dominant soil textures. SQI classified 11 samples as having good soil condition, 18 as moderate, and one as poor. The study concluded that most assessed rice farms were under moderate soil condition, indicating physical and biological limitations that may contribute to soil degradation. The VSA and SQI were useful in identifying variations in soil conditions and potential areas requiring improved soil management.

Keywords - Earthworms, land degradation, rice farms, soil quality, Soil Quality Index, Visual Soil Assessment

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I. INTRODUCTION

Land degradation, defined as the deterioration or loss of the present and future productive capacity of soils, affects everyone in various ways, including food shortages, higher food prices, climate change, environmental risks, and the loss of biodiversity and ecosystem services. The productivity of farmland and pastureland around the world is decreasing rapidly due to an alarming rate of land degradation. Globally, about 25% of the total land area has been degraded. In modern times, land degradation poses a serious global challenge. Various soil degradation processes cause over 5-6 million hectares of agricultural land worldwide to become unproductive each year [46]. In the Philippines, land degradation is also a major ecological concern. According to the National Action Plan (NAP), 5.2 million hectares are significantly degraded, which lowers soil production by 30 to 50% as of 2004 – 2010 [4]. Moreover, land and watershed degradation in some parts of Mindanao has created a need for sustainable land management practices that protect natural resources while supporting the livelihoods of farmers. As studies have found, sloping areas used for crops are notably susceptible to erosion and land degradation [32].

Soil quality is the bedrock for productive farming practices. It describes soil's ability to provide necessary nutrients to plants. Soil testing costs vary depending on the number and type of samples, while laboratory analyses are time-consuming [8]. The development of the VS-Fast methodology has addressed a significant requirement of the recently established methodological framework for the LADA program. The VS-Fast methodology is an improved and integrated method for field-based, farmer-usable visual assessment of soil quality and health, with a focus on simple, repeatable procedures using inexpensive, widely accessible equipment. This methodology includes observation of soil excavated using a shovel [27]. The Land Degradation Assessment in Drylands (LADA) project prepared guidelines and manuals assessing land degradation and sustainable land management at the global, national, and local levels. Barangay Montay, Datu Piang, Maguindanao del Sur is an agricultural area immensely producing rice and coconut as expressive yield.

Generally, the study aimed to provide the farmers and lawmakers with baseline data on soil quality in rice production areas in Barangay Montay, Datu Piang, Maguindanao Del Sur. Specifically, this study aimed to determine soil quality in terms of soil texture, structure, crusting, earthworm abundance, and plant root condition; identify rice production areas potentially undergoing degradation; and generate a soil quality index map of Barangay Montay, Datu Piang, Maguindanao Del Sur.

The expected output of the study is baseline information on the soil quality of rice production areas in Barangay Montay, Datu Piang, Maguindanao del Sur to help the farmers in their decision-making and guide the Department of Agriculture and the Ministry of Agriculture,

Fisheries and Agrarian Reform in developing plans for the area. The study was conducted in Barangay Montay, Datu Piang, Maguindanao del Sur, in rice production areas covering at least 1 ha. The data were gathered from August 19 to 20, 2023.

II. Review of Related Literature

A. Land Degradation Assessment in Drylands (LADA)

The Food and Agriculture Organization (FAO) led the Land Degradation Assessment in Drylands (LADA) initiative, which evaluated the causes and effects of land degradation at the global, national, and local levels to pinpoint problem areas and develop remedial actions. The initiative was funded by UNEP, GEF, and others. Land degradation is viewed by LADA as a biophysical, social, economic, and environmental problem that needs to be addressed using a variety of geo-informational, scientific, and local knowledge [21]. In addition, the FAO started the LADA initiative a few years ago. With the help of local communities and land users, the project aims to develop a set of standardized procedures and guidelines for evaluating the causes, processes, and impacts of land degradation [26]. Water quality, water consumption, and soil quality are the main focus of LADA environmental indicators. Other indicators also include general soil concerns, such as erosion, compaction, and nutrient loss [2].

Moreover, based on the presumption that human activities on the land are the primary causes of land degradation, the LADA approach was developed. Consequently, identifying and mapping various land use systems are very crucial activities for facilitating the assessment and its implementation [40].

LADA-local provides tools for assessing soil quality and properties. Visual Soil Assessment (VSA) is a tool to evaluate the physical condition of soil during field assessments. Additionally, it provides a primary indication of soil quality [13].

The field-based morphological state of soils is described and evaluated using the VS-Fast approach. Compared with traditional sets of soil physical measurements, it is a more rapid approach to soil assessment [33]. These approaches are appropriate for evaluating the structural quality of "tropical" soils across different soil types and land uses because they can distinguish among distinct soil structural qualities [34]. The visual soil assessment approach also provides a useful visual aid for increasing stakeholders' awareness of soil problems, facilitating the sharing of knowledge and ideas, and promoting agricultural innovation [6].

B. Soil Quality

The most effective sorts of indicators depend on the soil function for which soil quality is being assessed. These functions include providing a physical, chemical, and biological environment for living organisms; regulating and dividing water flow; storing and cycling nutrients and other elements; supporting biological activity and diversity for plant and animal productivity; filtering, buffering, decomposing, immobilizing, and detoxifying organic and inorganic contaminants; and providing mechanical support for living organisms and their structures [28].

In addition, soil quality is frequently evaluated based on its physical, chemical, and biological characteristics. Important indicators of soil quality for sustainable agricultural production include nitrogen, soil organic matter, soil texture, soil cation exchange capacity (CEC), soil acidity, salinity, and soil pH [17]. Given the significance of soils for agricultural output, food security and nutrition, farmer livelihoods, and a healthy and functioning ecosystem, the widespread occurrence of soil degradation necessitates a change in how we see and manage our soils [22]. Soil quality is crucial for obtaining high crop yields, which may decline under intensive farming without careful management [44]. The interaction between the water regime and cultivar, as well as the soil texture, has a significant impact on rice grain yield [18].

Sandy soil is more manageable compared to clay soils due to its lighter weight, resistance to compaction, and ease of digging and amending with compost. Additionally, most blooming plants thrive in sandy soil because of its excellent drainage. The risk of overwatering is low, and the likelihood of root rot is reduced [42]. Sandy loam is a soil composition predominantly consisting of sand with varied proportions of silt and clay. A significant number of individuals favor sandy loam soil due to its inherent ability to facilitate efficient drainage. Sand particles typically exhibit greater size and solidity compared to other particles present in the soil, resulting in greater permeability for water to flow unrestrictedly. Poor drainage can increase plants' susceptibility to excessive moisture, potentially leading to root rot and the development of diseases or fungal infections [43]. Silt loam is a soil composed of sand, silt, and clay in specific proportions. It is generally considered very fertile and suitable for agricultural purposes. The agricultural benefits of silt loam soil include its capacity to retain water and nutrients, as well as its drainage properties [1]. Loam is a soil texture characterized by a relatively balanced mixture of silt, sand, and clay particles. This composition provides favorable properties for landscaping, agriculture, and gardening.

Clay loam soil is impenetrable and difficult for water to pass through since it is finely textured. It is the best soil texture for growing rice; it holds onto water and prevents it from draining away. Compared with other types of crops, rice that is traditionally cultivated in paddies requires substantial amounts of water and needs standing water to start the growing process [31].

One of the most significant properties affecting crop production is soil structure. It controls root growth, water retention, and the movement of air, water, and soil flora through the soil [37].

In direct-seeded fields, crusting significantly reduces crop stand. Due to a decreased plant stand and accompanying decrease in yield, it has a direct economic

impact. The germinating seeds are unable to break the crust when the soil is experiencing crusting; it limits the flow of oxygen into and out of the soil, thus reducing crop growth [39].

Earthworms are essential soil organisms that support plant growth and development by enhancing the soil's physical and chemical properties and increasing soil biodiversity, thereby playing a key role in the provision of ecosystem services [26]. Alves et al. [3] found that several commonly used pesticides significantly affected earthworm populations. The study reported reduced earthworm reproduction after exposure to imidacloprid, fipronil, carboxin + thiram, captan, and thiamethoxam, while avoidance behavior was observed when earthworms were exposed to imidacloprid, captan, carboxin + thiram, and thiamethoxam. The reported EC50 and AC50 values indicate the concentrations at which these pesticides caused measurable adverse effects. Imidacloprid showed the greatest toxicity, requiring only a small concentration to reduce reproduction (EC50 = 4.07 mg kg^{-1}) and induce avoidance behavior (AC50 = 0.11 mg kg^{-1}). These findings demonstrate that pesticide contamination can reduce earthworm abundance and activity, thereby impairing soil biological health.

Since root development plays a significant role in a plant's ability to withstand abiotic pressures like drought and salinity, controlling root growth and development could represent a valuable strategy for increasing a plant's ability to withstand abiotic stresses. Root development has a significant impact on the growth and production of plants because roots anchor plants and absorb water and nutrients from the soil [41].

C. Geographic Information System (GIS)

Quantum GIS (QGIS) is free and open-source software released in 2002. This software, which welcomes user involvement in the form of code, tool advancement, problem reports/fixes, records, and advocacy/support, is powered by volunteers [23].

To successfully combat land degradation, it is necessary to have a better awareness of its causes, effects, and level, and knowledge of the climate, water, soil, surface area, and socioeconomic factors. The development of an evidence-based and effective land management plan requires an assessment of land degradation. Mapping and assessing land degradation status is essential for identifying vulnerable areas and developing sustainable landscape management [20].

Furthermore, a primary issue is soil degradation in agricultural rain-fed areas, which is mostly caused by water-induced erosion. Farmers and local and national governments all face difficulties in the plans for implementing sustainable agricultural land management, particularly in securing funding and transforming value systems from short-term production-oriented approaches toward long-term conservation, environmental stewardship, and sustainable land management [16]. Participatory mapping of land degradation areas to promote community involvement in the consequent restoration operations is the main strategy of the FAO-LADA approach [15].

III. METHODOLOGY

This study adapted the methodological framework (Figure 1) presented in the Land Degradation Assessment in Drylands (LADA) Manual for Local Level Soil Assessment (2016).

The field assessment employed the Visual Soil Assessment (VSA) method. A modified field manual was used to assess the soil condition and estimate the status of soils in the rice fields. Soil quality was evaluated based on visual scorecards completed during the field assessment. The results were subsequently mapped to provide a graphical representation of the soil conditions within the study area.

Additionally, the results were projected and visualized using the Quantum Geographic Information System (QGIS). This mapping component was incorporated into the study and was not included in the original methodology of the LADA Manual for Local Level Soil Assessment.

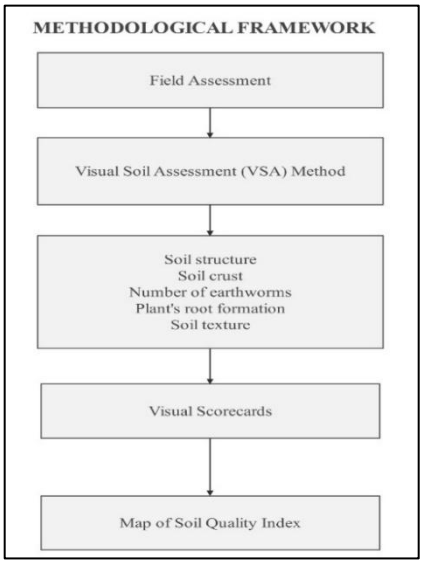

Fig. 1. **Conceptual Framework of the Assessment Method**.

Datu Piang falls under Type III climate, characterized by the absence of a pronounced wet or dry season. The municipality experiences relatively dry conditions during the early part of July, August, September, October, and the latter part of December. Moderate rainfall typically occurs in May, June, and November, while the lowest rainfall is recorded in January, February, March, April, and the early part of December. The area is partly sheltered from the northeast monsoon (Amihan) but is exposed to the southwest monsoon (Habagat), two major monsoon systems that influence the Philippine climate. As a result of its low-lying topography, Datu Piang is highly

susceptible to flooding, with approximately 80% of its lowland areas frequently affected.

During the relatively dry months, average monthly rainfall ranges from 120 to 135 mm. The highest average monthly rainfall occurs between May and June, reaching approximately 210 mm.

A. Materials

The basic tools and materials used in the field assessment and data analysis, along with their functions, are listed in Table 1.

TABLE 1**. BASIC TOOLS AND MATERIALS USED IN THE STUDY**

TOOLS AND MATERIALS	FUNCTIONS
Measuring tape	To measure the sampling depth and topsoil thickness
Shovel	To dig a soil pit and take a 20 x 20 x 25 cm cube of soil for the drop shatter soil structure test
Water	To assess the field soil textural class and color
Sack	To serve as a recipient to which the soil cube is dropped
VS-fast score sheet	To record the visual score (VS) for each indicator
Manual Field Guide	To make photographic comparisons and scoring guidelines for field assessment
Phone (with Timestamp Camera Application)	To get the point of the locations of samples
Laptop (with QGIS and Excel software)	To generate map of the soil quality

B. Locale of the Study

Barangay Montay, Datu Piang, Maguindanao del Sur (Figure 2) is geographically located at approximately 7.0093494°N latitude and 124.422656°E longitude.

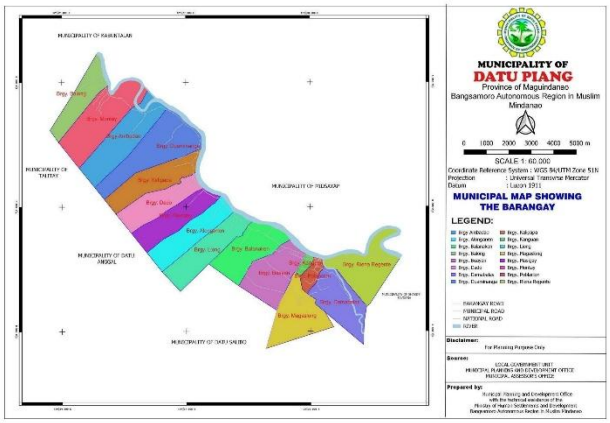

Fig. 2. **Map of Datu Piang, Maguindanao Del Sur**

Visual Soil Assessment (VSA) was carried out at farm lands under rice cropping systems in Barangay Montay, Datu Piang, Maguindanao Del Sur. Ten sites were selected based on the scope of the study. Table 2 presents the coordinates of the sites. Each site covered an area of at least 1 ha and was planted with lowland rice only (no intercrop). Nine (9) sites are located on the right side of the barangay road approximately 500 meters away and near the Pulangi River, and one site is on the other side of the road approximately 300 meters away

TABLE 2. **LOCATIONS**

SITE	LATITUDE	LONGITUDE
Montay 1a	7.0940	124.4227
Montay 1b	7.0936	124.4233
Montay 1c	7.0932	124.4239
Montay 2a	7.0935	124.4241
Montay 2b	7.0939	124.4234
Montay 2c	7.0944	124.4228
Montay 3a	7.0937	124.4242
Montay 3b	7.0941	124.4237
Montay 3c	7.0947	124.4230
Montay 4a	7.0954	124.4235
Montay 4b	7.0951	124.4239
Montay 4c	7.0947	124.4244
Montay 5a	7.0956	124.4237
Montay 5b	7.0953	124.4241
Montay 5c	7.0949	124.4245
Montay 6a	7.0953	124.4251
Montay 6b	7.0957	124.4247
Montay 6c	7.0962	124.4240
Montay 7a	7.0977	124.4251
Montay 7b	7.0971	124.4258
Montay 7c	7.0965	124.4264
Montay 8a	7.0956	124.4254
Montay 8b	7.0960	124.4249
Montay 8c	7.0964	124.4243
Montay 9a	7.0980	124.4253
Montay 9b	7.0974	124.4261
Montay 9c	7.0968	124.4267
Montay 10a	7.0917	124.4226
Montay 10b	7.0905	124.4219
Montay 10c	7.0896	124.4212

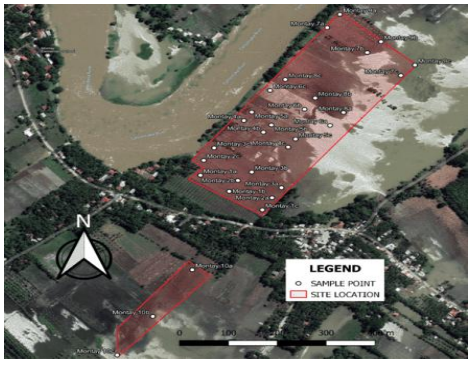

Fig. 3. **Map of Soil Samples**

C. The Visual Soil Assessment (VSA) Method

VSA was based on the evaluation of key soil quality performance indicators presented on a scorecard. The main soil properties assessed were soil structure, soil texture, soil color, earthworm abundance, soil crusting, and plant root development.

Each indicator, except soil color and soil texture, was given a visual score (VS) of 0 (poor), 1 (moderate), or 2 (good), based on the criteria specified in the field manual. The scoring system allowed intermediate scores when the assessed sample did not clearly match any of the descriptions and photographs provided in the field manual. Scores of 0.5 or 1.5 could be assigned when the observed condition fell between two scoring categories. Assessment Process of Visual Indicators

The sampling was done by excavating 20 cm x 20 cm x 25 cm soil depth using a shovel. Three (3) samples were gathered for each area, with 100 m distance from each other.

D. Sampling Protocol for Textural Group

Soil texture was evaluated in the field by placing one or two tablespoonfuls of soil from each sample in one hand and adding water drop by drop while working the soil by hand until it reached the sticky consistency. The soil was rolled into a ball, and its texture was determined by how well it could take different shapes (Figure 4). The resulting soil texture was then classified according to the criteria presented in Table 3.

TABLE 3. **SOIL TEXTURE DESCRIPTION**

Soil Texture	Description
A **Sandy**	The soil stays loose and separated and can be accumulated only in the form of pyramid
B **Sandy loam**	The soil has the consistency of an easy-to-take-part ball and is enough silty and clayey to become sticky.
C **Silty Loam**	Rolling the soil into a small, narrow cylinder will give it shape.
D **Loam**	Consists primarily of clay, silt, and sand. can be rolled into a cylinder that is about 14 cm long.
E **Clayey loam**	But unlike loam, the rolled cylinder can be bent and given a "U" shape without being overworked and broken.
F **Fine clay**	Although it may be bent into a round, the soil cylinder has some cracks.
G **Heavy clay**	There are no fissures in the soil's circular shape.

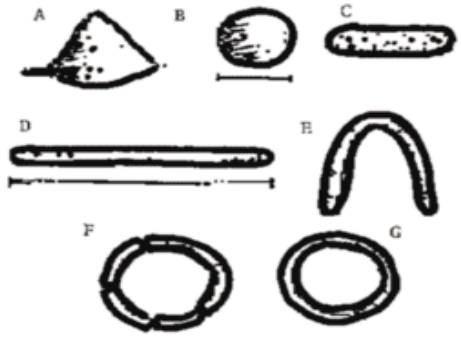

Fig. 4. **Hand Assessment of soil texture (adopted from LADA-manual)**

E. Sampling Protocol for Soil Structure

A 20 cm width by 25 cm depth of the topsoil was removed using a shovel. The drop-shatter test was utilized to standardize the method used for moving the soil with the spade. A white sack was the recipient of a maximum of three drops of the soil sample from a height of one hundred centimeters (Figure 5). The largest fractions were shifted to one end, and the smallest fractions to the other. The distribution of aggregates was set up on the white sack such that the soil height is uniform across its entire surface area (Figure 6). It was then compared with the reference photograph (Figure 7).

According to VS-Fast, the description of soil structure concentrates on the presence of "pans" in the soil, which are platy, massive, continuous, horizontal layers, as well as the size and shape of soil aggregates. The presence of pans was scored using Table 4, adapted from LADA-local manual (2016).



Fig. 5. **Dropping the soil sample for the shatter**



Fig. 6. **Arranging the soil aggregate to assess soil structure**



Fig. 7. **Arranging the soil aggregate to assess soil structure**

TABLE 4. **VISUAL SCORING FOR PRESENCE OF PAN**

Sub - indicators	**Observation and Score**
No tillage pans or any presence if pan, with friable structure and soil pores from top soil to subsoil	2 = Good Condition
Firm, moderately developed tillage pans in the lower topsoil or upper subsoil, or surface pan from animals or reaped traffic. Areas of better soil structure recorded above or below the pan, cracks or continuous pores through pan	1= Moderate condition
A well-developed tillage pans in the lower topsoil, or surface pan from animals or repeated traffic. The pan has a massive or platy structure and very few or no vertical cracks or pores through the pan.	0=Poor Condition



Fig. 8. **Soil Crust**

F. Sampling Protocol for Soil Crust

Soil crusting is a surface phenomenon that may result from processes such as trampling. Soil crusts were observed and recorded based on the guidelines provided in the LADA local manual (Figure 8) and scored using the criteria presented in Table 5.

TABLE 5. **VISUAL SCORING FOR SOIL CRUST**

Sub - indicators	**Observation and Score**
Few or no surface crusts.	2 = Good Condition
Up to 3mm thick, broken by cracking	1= Moderate condition
Up to 10mm thick, continuous with almost no cracking.	0=Poor Condition

G. Sampling Protocol for Numbers of Earthworms

Soil biota can serve as an indicator of soil quality. Earthworms are useful indicators because they incorporate organic matter into the soil and increase soil aeration. All earthworms identified in the soil sample from the 20 cm × 20 cm pit to a depth of 25 cm were picked out (Figure 9) and set aside while the soil was worked with the shovel blade to analyze the soil structure. The number of earthworms was counted. It was scored using the criteria in Table 6, adapted from LADA-local manual (2016).



Fig. 9. **Number of Earthworms**

TABLE 6. **VISUAL SCORING FOR NUMBER OF EARTHWORMS**

Sub - indicators	**Observation and Score**
>8 earthworms counted	2 = Good Condition
4 to 8 earthworms counted	1= Moderate condition
<4 earthworms counted	0=Poor Condition

H. Sampling Protocol for Plants' Root Formation

The plant was picked out carefully (Figure 10) and observed the formation of roots. It was scored using Table 7 adapted from LADA local manual (2016).



Fig. 10. Plant's root

I. Indicators of Soil Quality Performance

Weighing factors of 1, 2, and 3, adapted from LADA-L, were assigned to the soil quality indicators. The total of the VS rankings yields the overall SQI score for each sample evaluated. The overall SQI score was then compared with the rating scale at the bottom of the scorecard to classify the soil as good, moderate, or poor condition.

TABLE 8. VISUAL INDICATORS TO ASSESS SOIL QUALITY PERFORMANCE (ADOPTED FROM LADA 2016)

Visual indicators of soil quality	**VISUAL SCORE (VS) 0= poor condition 1 = moderate condition 2 = good condition**	**Weighting**	**VS – ranking**
Tillage Pan		×3	
Aggregate Size Distribution		×3	
Soil Crust		×2	
Earthworms		×3	
Roots		×3	
Sum of the visual score			
Soil Visual Assessment		**Soil Quality Index**	
Poor		<7	
Moderate		7-14	
Good condition		15-26	

TABLE 7. VISUAL SCORING FOR PLANT ROOT FORMATION

Sub - indicators	**Observation and Score**
Unrestricted root development	2 = Good Condition
Limited horizontal and/or vertical root development	1= Moderate condition
Severe restriction of horizontal and vertical root development.	0=Poor Condition

J. Mapping of Soil Quality Assessment Results

To provide a graphical representation of the study area, the Timestamp camera application was used to obtain GPS coordinates. The coordinates were encoded in Microsoft Excel and imported into Google Earth to identify the corresponding areas for digitization. The map was then generated using Quantum Geographic Information System (QGIS).

The VSA scores obtained from the sampling locations were spatially interpolated using the Inverse Distance Weighting (IDW) method in QGIS to generate continuous thematic maps of soil quality indicators.

The map generated used three coloring schemes: red, green, and yellow. Based on the sum of the VS-fast scores obtained during the field assessment, the color red indicated that the soil of the farm is visually classified as being in poor condition. Green indicated good soil condition, while yellow indicated moderate soil condition.

K. Statistical Analysis

Descriptive statistics were used to analyze and interpret data collected during the assessment of soil quality in the rice farming systems.

IV. Results and Discussion

A. Visual Indicators Used in the Assessment

Ten rice farm sites that covered at least 1 ha were identified. The visual assessment of each site took 10 to 20 minutes. An addition 15 minutes for computation and tabulation of the results was allotted per site. To sum up, the soil assessment of each site took 25 to 35 minutes to complete.

B. Soil Structure

Soil structure was assessed based on aggregate size distribution, considering the size, shape, firmness, and relative abundance of soil aggregates and clods. Soil with good structure was characterized by a well-distributed mixture of smaller, friable aggregates with no significant number of clods. In contrast, soil with poor structure was dominated by large, completely firm clods with very few small, breakable aggregates and the presence of pans. The presence of pans was considered an important negative indicator of soil condition and a potential sign of unsustainable land management practices. Soil with good

structure had no tillage or surface pans, with friable structure and soil pores from topsoil to subsoil. In contrast, soil with poor structure had a well-developed pan in the lower topsoil or a surface pan resulting from animal trampling or repeated traffic. These pans had a massive or platy structure, with very few or no vertical cracks or pores extending through them.

Table 9a presents the assessment of soil structure based on aggregate size distribution in the rice farms of Barangay Montay. Samples from Montay 1B, 1C, 3A, 3B, 3C, 4A, 5A, 5B, 6C, 7A, 7B, and 7C showed good distribution of friable, smaller aggregates with no significant clodding. This condition indicates relatively favorable structural quality because friable aggregates generally promote the development of interconnected pore spaces that facilitate water movement, air exchange, and root penetration. Bronick and Lal [10] emphasized that well-developed soil structure contributes to improved water transmission and storage, reduced susceptibility to erosion, and favorable conditions for plant-root growth.

On the other hand, the samples from Montay 2C, 4C, 6A, 8C, 9B, 10A and 10C were characterized by soil dominated by large, firm clods with very few small and breakable aggregates. This condition indicates poor soil structural quality because the dominance of firm clods may reduce the continuity of pores and create physical resistance to water infiltration and root penetration. According to Batey [7], soil compaction and structural degradation can reduce pore space and hydraulic conductivity, resulting in restricted root development and impaired soil functions.

Table 9b presents the assessment of soil structure in terms of the presence and severity of soil pans. Samples from Montay 2A, 4B, 4C, 5B, 5C, 6A, 7A, and 8A exhibited minimal or no evidence of a tillage pan and generally showed friable soil with visible pores extending from the topsoil toward the subsoil. This condition suggests relatively continuous pore networks that can facilitate root penetration, aeration, and water movement. The absence or limited occurrence of compacted layers is considered favorable because roots and water can move more freely through the soil profile.

In contrast, samples from Montay 1A, 1B, 1C, 2B, 2C, 4A, 5A, 6B, 6C, 7B, 7C, 8B, 8C, 9A, 9B, 9C, 10A, 10B, and 10C exhibited a firm and moderately developed pan in the lower topsoil. The samples from Montay 3 showed a well-developed pan in the lower topsoil, representing the most severe pan condition observed during the assessment. Soil pans can develop as a result of repeated mechanical disturbance or pressure at similar depths, including repeated tillage operations and traffic from agricultural machinery or animals. However, because the sources and intensity of traffic were not directly measured in this study, the observed pans should be interpreted as evidence of soil compaction rather than being attributed to a specific cause lower topsoil.

TABLE 9A. SOIL STRUCTURE ASSESSMENT (AGGREGATE SIZE DISTRIBUTION) OF RICE FARMS IN MONTAY, DATU PIANG, MAGUINDANAO DEL SUR, AUGUST 20, 2023

SITE LOCATION	SAMPLE	VISUAL SCORE
Montay 1	A	1
	B	2
	C	2
Montay 2	A	1
	B	1
	C	0
Montay 3	A	2
	B	2
	C	2
Montay 4	A	2
	B	1
	C	0
Montay 5	A	2
	B	2
	C	1
Montay 6	A	0
	B	1
	C	2
Montay 7	A	2
	B	2
	C	2
Montay 8	A	1
	B	1
	C	0
Montay 9	A	1
	B	0
	C	1
Montay 10	A	0
	B	1
	C	0

TABLE 9B. SOIL STRUCTURE ASSESSMENT (PRESENCE OF SOIL PANS) OF RICE FARMS IN MONTAY, DATU PIANG, MAGUINDANAO DEL SUR, AUGUST 20, 2023

SITE LOCATION	SAMPLE	VISUAL SCORE
Montay 1	A	1
	B	1
	C	1
Montay 2	A	2
	B	1
	C	1
Montay 3	A	0
	B	0
	C	0
Montay 4	A	1
	B	2
	C	2
Montay 5	A	1
	B	2
	C	2
Montay 6	A	2
	B	1
	C	1

Montay 7	A	2
	B	1
	C	1
Montay 8	A	2
	B	1
	C	1
Montay 9	A	1
	B	1
	C	1
Montay 10	A	1
	B	1
	C	1

C. Soil Crust

Table 10 presents the visual assessment of soil surface crusting in the rice farms of Barangay Montay, Datu Piang, Maguindanao del Sur. Based on the criteria, a visual score of 2 indicates little or no surface crusting; a score of 1 indicates moderate crusting characterized by approximately 2–3 mm thick crust broken by cracks; and score of 0 indicates poor condition, characterized by relatively continuous and thicker surface crusting with limited cracking. Surface crusting is considered a negative physical soil indicator because consolidated surface layers can restrict water infiltration and impede seedling emergence [21].

Of the 30 observations, 19 received a visual score of 1, six received a score of 2, and five received a score of 0. The predominance of a visual score of 1 indicates that moderate surface crusting was the most common condition among the assessed rice farms. The approximately 3-mm crusts observed at these sites were already broken by cracking, suggesting an intermediate condition rather than the severe, continuous crusting associated with the poorest VSA category.

The five observations with a visual score of 0, recorded at Montay 3A, 8A, 8C, 9B, and 9C, indicate localized areas of more severe surface crusting. These areas may have greater potential for restricted infiltration and increased surface runoff compared with sites having little or moderately developed crusts.

The observed crusting may also be associated with the rainfed nature of rice production in the study area. Repeated rainfall and raindrop impact on exposed soil surfaces can promote aggregate breakdown and crust formation.

TABLE 10. SOIL CRUST ASSESSMENT OF RICE FARMS IN MONTAY, DATU PIANG, MAGUINDANAO DEL SUR, AUGUST 20, 2023

SITE LOCATION	SAMPLE	VISUAL SCORE
Montay 1	A	1
	B	1
	C	1
Montay 2	A	1
	B	1
	C	1
Montay 3	A	0
	B	1
	C	1
Montay 4	A	1
	B	2
	C	2
Montay 5	A	1
	B	2
	C	2
Montay 6	A	1
	B	1
	C	1
Montay 7	A	2
	B	1
	C	2
Montay 8	A	0
	B	1
	C	0
Montay 9	A	1
	B	0
	C	0
Montay 10	A	1
	B	1
	C	1

D. Number of Earthworms

Table 11 presents the number of earthworms observed in soil samples collected from the rice farms of Barangay Montay, Datu Piang, Maguindanao del Sur. Earthworms are considered important soil biological indicators because their burrowing and feeding activities can influence soil structure, aggregation, aeration, water movement, organic-matter incorporation, and nutrient cycling. Consequently, the presence and abundance of earthworms can provide useful information regarding the biological condition of agricultural soils.

The assessment showed that 29 out of 30 soil samples contained fewer than four earthworms, while the sample from Montay 3A was the only one with a higher abundance. The generally low number of earthworms observed across the study sites suggests limited earthworm activity in the sampled rice soils. This condition may indicate reduced biological activity and may be associated with management or environmental conditions that are less favorable to earthworm populations.

Through burrowing, casting, and incorporation of organic materials, earthworms can modify soil aggregation, porosity, water infiltration, nutrient availability, and microbial activity [9]. Therefore, the relatively low earthworm abundance observed in most of the Montay samples may represent a biological limitation in comparison with soils supporting more abundant earthworm populations.

The low abundance of earthworms may be associated with several factors. Agricultural practices such as intensive tillage, removal of crop residues, limited organic-matter inputs, and the use of agricultural chemicals can alter the habitat and food resources required by earthworms. Soil moisture and temperature may also influence earthworm activity and detectability during field assessment. These factors are particularly relevant in rice

production systems where soil water conditions can change substantially between cropping and fallow periods.

Pesticide application may also be a potential contributing factor. Previous studies have shown that some pesticides can adversely affect earthworm survival, growth, reproduction, and behavior [38]. Organophosphate insecticides such as chlorpyrifos and pyrethroid insecticides such as cypermethrin have been reported to cause adverse effects on earthworms under certain exposure conditions. Thus, the use of these pesticides in rice production may have contributed to the low earthworm abundance observed in some fields. However, because pesticide concentrations, application rates, application frequency, and residual concentrations in the soil were not measured in the present study, a direct causal relationship between pesticide use and the observed earthworm abundance cannot be established.

TABLE 11. NUMBER OF EARTHWORMS FOUND IN THE RICE FARMS IN MONTAY, DATU PIANG, MAGUINDANAO DEL SUR, AUGUST 20, 2023

SITE LOCATION	SAMPLE	VISUAL SCORE
Montay 1	A	0
	B	0
	C	0
Montay 2	A	0
	B	0
	C	0
Montay 3	A	1
	B	0
	C	0
Montay 4	A	0
	B	0
	C	0
Montay 5	A	0
	B	0
	C	0
Montay 6	A	0
	B	0
	C	0
Montay 7	A	0
	B	0
	C	0
Montay 8	A	0
	B	0
	C	0
Montay 9	A	0
	B	0
	C	0
Montay 10	A	0
	B	0
	C	0

E. Plants' Root Development

Root system development in the soil is a prime biological indicator of soil quality. When plant root growth is not impeded, roots can develop more fully and optimize uptake of water and nutrients to meet plant demand. Root formation is also influenced by soil properties such as soil structure and texture.

Table 12 shows the assessment of plants root development in the rice farms of Barangay Montay. The samples from Montay 1A, 1B, 2A, 2B, 3Q, 3B, 3C, 4B, 4C, 5A, 5B, 5C 6B, 6C, 7A, 8A, 8B and 8C showed unrestricted root development. This demonstrates the ability of roots to penetrate into the soil and access water within it. In contrast, the sample from Montay 7C showed severe restriction of horizontal and vertical root development, indicating poor root growth. The samples from Montay 1C, 2C, 4A, 6A, 7B, 9A, 9B, 9C, 10A, 10B and 10C were revealed to have limited horizontal and vertical root development. In addition, interview data revealed that a pesticide containing cypermethrin was applied and, accordingly, excessive exposure of plants in this pesticide ingredient can restrain root elongation and reduce root biomass in plants, potentially due to disruptions in ion transport and membrane integrity.

TABLE 12. PLANT'S ROOTS FORMATION IN THE RICE FARMS IN MONTAY, DATU PIANG, MAGUINDANAO DEL SUR, AUGUST 20, 2023

SITE LOCATION	SAMPLE	VISUAL SCORE
Montay 1	A	2
	B	2
	C	1
Montay 2	A	2
	B	2
	C	1
Montay 3	A	2
	B	2
	C	2
Montay 4	A	1
	B	2
	C	2
Montay 5	A	2
	B	2
	C	2
Montay 6	A	1
	B	2
	C	2
Montay 7	A	2
	B	1
	C	0
Montay 8	A	2
	B	2
	C	2
Montay 9	A	1
	B	1
	C	1
Montay 10	A	1
	B	1
	C	1

F. Soil Texture

Table 13 shows the results of the soil texture assessment conducted at 10 rice farm sites in Barangay Montay, Datu Piang, Maguindanao del Sur. The results revealed that sand, sandy loam, and silt loam were the predominant textural classes among the assessed samples, while loam was observed at Montay 10. Soil texture is an important inherent soil property because the relative

proportions of sand, silt, and clay influence pore-size distribution, water movement, water retention, nutrient storage, aeration, and root development. Consequently, soil texture is commonly considered an important physical indicator in soil-quality assessment [29],[12].

The occurrence of sandy soils in some of the Montay rice farms indicates a relatively coarse soil texture. Sandy soils generally contain a high proportion of large particles and macropores, allowing water to move rapidly through the soil. Consequently, they tend to have relatively high infiltration and drainage but comparatively low water-retention capacity. Assouline [5] emphasized that soil texture strongly influences soil-water retention characteristics because particle-size distribution determines the pore-size distribution of the soil. Therefore, although sandy soils may be less susceptible to prolonged waterlogging, their low water-retention capacity may result in more rapid loss of soil moisture during periods without rainfall. This characteristic is particularly relevant to the rainfed rice farms of Montay, where crop water availability depends substantially on rainfall.

The sandy loam soils observed in the study represent an intermediate textural condition between sandy and finer-textured soils. Sandy loam generally provides relatively good drainage while retaining more water than sand because the addition of finer particles increases the proportion of smaller pores. Soil texture therefore affects the balance between drainage and water storage rather than determining whether a soil is simply "good" or "poor." Experimental studies have demonstrated that changes in soil texture can substantially influence infiltration and hydraulic behavior, although the actual infiltration rate is also affected by soil structure, compaction, organic matter, and management practices.

The presence of silt loam at several sites indicates a relatively finer texture compared with sand and sandy loam. Silt loam soils generally contain a greater proportion of intermediate-sized particles and consequently have greater water-retention capacity than coarse sandy soils. However, soils with substantial silt content may also be susceptible to surface sealing and compaction when exposed to rainfall and mechanical disturbance. This is important in the present study because surface crusting was also observed in several Montay rice farms. The interaction between texture and surface condition may therefore influence infiltration and soil-water availability. Research on agricultural soils has demonstrated that soil hydraulic properties are affected not only by texture but also by tillage-induced changes in macroporosity and soil structure [11].

The occurrence of loam soil at Montay 10 indicates a more balanced proportion of sand, silt, and clay particles. Loam soils generally provide a balance between water retention and drainage because they contain both relatively large and small pores. However, the actual hydraulic and agronomic behavior of a loam soil depends on its specific particle-size distribution, organic-matter content, aggregation, and bulk density.

The observed variation in soil texture among the Montay sites is important for interpreting the other soil quality indicators assessed in this study. For example, soil texture can influence infiltration, moisture availability, compaction, earthworm habitat, and nutrient retention. Lima et al. [30], in a study of rice production systems, found that soil texture was important in differentiating soil conditions and that properties such as bulk density and available water were particularly useful in distinguishing soil textural classes. Their findings demonstrate that soil-quality assessment in rice systems should consider texture together with other physical, chemical, and biological indicators.

TABLE 13. SOIL TEXTURE ASSESSMENT OF RICE FARMS IN MONTAY, DATU PIANG, MAGUINDANAO, DEL SUR, AUGUST 20, 2023

SITE LOCATION	SAMPLE	SOIL TEXTURE
Montay 1	A	Silty loam
	B	Silty loam
	C	Silty loam
Montay 2	A	Silty loam
	B	Silty loam
	C	Sandy
Montay 3	A	Sandy loam
	B	Sandy loam
	C	Sandy
Montay 4	A	Sandy
	B	Sandy loam
	C	Sandy loam
Montay 5	A	Sandy
	B	Sandy loam
	C	Sandy loam
Montay 6	A	Sandy loam
	B	Sandy loam
	C	Sandy
Montay 7	A	Sandy loam
	B	Sandy loam
	C	Silty loam
Montay 8	A	Sandy loam
	B	Sandy loam
	C	Sandy
Montay 9	A	Sandy loam
	B	Sandy loam
	C	Silty loam
Montay 10	A	Loam
	B	Silty loam
	C	Loam

G. Soil Quality Index

The overall soil quality condition of the assessed rice farms was determined by summing the visual scores of selected physical and biological soil indicators, including soil structure, soil crust, earthworm abundance, tillage pan, and plant root development. The resulting composite score was used as a Visual Soil Quality Index (SQI) to classify the

condition of each sampling site into good, moderate, or poor condition. Previous studies have demonstrated that integrated soil quality indices combining physical, morphological, chemical, and biological indicators provide a more comprehensive evaluation of soil functioning and can be used to identify changes associated with land degradation and land management practices [35], [45].

Table 14 shows that samples from Montay 1B, 2A, 3C, 4B, 4C, 5A, 5B, 5C, 6C, 7A, and 8A were classified as having good soil condition based on their relatively high composite visual scores. In contrast, the sample from Montay 9B was classified as having poor soil condition, with a total score of 6. The remaining 18 samples were classified as having moderate soil condition. The predominance of samples under moderate condition indicates that the assessed rice farms generally exhibited intermediate soil quality, with some indicators showing favorable conditions while other indicators suggested physical or biological limitations.

The interpretation of the composite score is relevant to land degradation because declining soil quality is commonly associated with deterioration of the soil's capacity to perform essential functions, including water storage and transmission, nutrient cycling, root development, and biological activity. Recent studies have demonstrated that Soil Quality Index values generally decline with increasing land degradation intensity. Gao et al. [24], for example, found that increasing land degradation resulted in significant reductions in Soil Quality Index values and crop productivity, confirming that integrated soil indicators can provide useful information for evaluating the effects of degradation on agricultural land.

Good Soil Condition

The samples classified under good condition generally obtained higher scores because they exhibited relatively favorable combinations of soil structure, limited surface crusting, lower occurrence of restrictive tillage pans, greater root development, and/or more favorable biological activity. Visual soil assessment studies have shown that soil structural characteristics, earthworm abundance, compacted layers, and root development can provide useful information regarding the ability of soil to perform essential agricultural and environmental functions [35], [19].

Montay 1B obtained a composite score of 17 and was classified as having good soil condition. The site was characterized by a silty loam texture, relatively well-developed soil structure, limited surface crusting, unrestricted root development, and only a moderately developed tillage pan. These characteristics suggest that the soil retained a relatively favorable balance between soil aggregation and root penetration. Visual assessments of soil structure have also been found to be associated with quantitative physical and biochemical soil properties, supporting their use as indicators of soil functioning [13].

Similarly, Montay 2A obtained a score of 17 and was classified under good soil condition. The site had a silty loam texture, moderate soil structure, limited occurrence of a tillage pan, and unrestricted plant root development. The combination of these indicators suggests that the soil did not exhibit severe physical restrictions to root penetration. Root development is particularly important in soil-quality assessment because roots interact with soil structure and pore networks and contribute to the formation of biopores that facilitate water movement, aeration, and further root penetration.

Montay 3C was also classified as having good soil condition. The sample exhibited a relatively favorable soil structure, moderate surface crusting, unrestricted root development, and a moderately developed tillage pan. Although the soil had a sandy texture, the overall classification was based on the combined performance of several indicators rather than soil texture alone. Soil structure, organic matter, compaction, biological activity, and management practices also influence soil functioning. Therefore, the good condition observed at Montay 3C reflects the combined condition of the assessed indicators rather than the inherent advantage of sandy texture alone.

Montay 4B and 4C were likewise classified as having good soil condition. Both samples exhibited sandy loam texture and relatively favorable physical characteristics, including few surface crusts, limited presence of tillage pans, and unrestricted plant root development. These observations suggest relatively limited physical constraints to water movement and root penetration. The absence or limited occurrence of compacted layers is particularly important because compacted soil can restrict root growth, reduce pore continuity, and limit water infiltration.

Samples from Montay 5A, 5B, and 5C also demonstrated good soil condition based on their relatively high composite scores. These samples generally exhibited favorable aggregate distribution, limited to moderate development of tillage pans, few or limited surface crusts, and unrestricted root development. Soil aggregation is an important component of soil quality because stable and friable aggregates contribute to pore development, water movement, aeration, and resistance to physical degradation.

Montay 6C, 7A, and 8A were also classified as having good soil condition. Despite variations in soil texture and the presence of some moderate limitations, these samples retained relatively favorable overall scores because they exhibited combinations of good aggregate distribution, limited or moderate tillage pan development, and unrestricted root formation. This demonstrates that the Soil Quality Index provides an integrated evaluation in which individual limitations do not necessarily result in poor overall soil condition when other indicators remain favorable.

Moderate Soil Condition

The remaining 18 samples were classified as having

moderate soil condition. This classification indicates that the samples exhibited intermediate characteristics, with neither consistently favorable nor severely degraded conditions across the assessed indicators. Moderate condition may reflect the occurrence of one or more physical or biological limitations, such as moderate surface crusting, moderately developed tillage pans, reduced earthworm abundance, or less favorable soil aggregation.

The dominance of moderate soil condition among the assessed samples suggests that soil degradation processes may be occurring at an intermediate level in several areas but have not resulted in uniformly poor soil condition. Land degradation commonly occurs gradually through changes in multiple soil properties rather than through deterioration of a single indicator. Therefore, moderate SQI scores may serve as an early warning that soil management interventions are needed to prevent further decline in soil functions.

Poor Soil Condition

Montay 9B was classified as having poor soil condition, with a composite score of 6, which was the lowest score among the assessed samples. The site was characterized by soil dominated by large, completely firm clods with very few small and breakable aggregates, a moderately developed tillage pan, and continuous surface crusting with cracking. These characteristics indicate unfavorable soil physical conditions and suggest a greater degree of structural degradation than those observed in the other sampling sites.

The occurrence of large and firm clods may indicate poor soil aggregation and reduced structural quality. Combined with the presence of a tillage pan, these conditions may restrict root penetration and reduce soil pore continuity. Continuous surface crusting can further limit water infiltration and increase the potential for surface runoff. The simultaneous occurrence of unfavorable structural conditions, compaction, and crusting is particularly significant because land degradation often involves interacting processes that collectively reduce soil functions rather than isolated changes in individual soil properties.

The low composite score of Montay 9B therefore indicates poor soil condition and a potentially greater level of land degradation relative to the other sampling sites. A recent study using Visual Soil Assessment demonstrated that indicators including earthworm abundance, soil structure, compacted layers, and surface characteristics were sensitive to differences in disturbance and preservation levels, supporting the use of integrated visual indicators for evaluating changes in soil condition.

The results of the potentially degrading lands are projected on Quantum GIS (Figure 11)

TABLE 14. SOIL QUALITY INDEX OF RICE FARMS IN MONTAY, DATU PIANG, MAGUINDANAO DEL SUR

SITE LOCATION	SAMPLE	SUM OF THE VS-FAST SCORE	DESCRIPTION
Montay 1	A	14	Moderate Soil Condition
	B	17	Good Soil Condition
	C	14	Moderate Soil Condition
Montay 2	A	17	Good Soil Condition
	B	14	Moderate Soil Condition
	C	8	Moderate Soil Condition
Montay 3	A	12	Moderate Soil Condition
	B	14	Moderate Soil Condition
	C	17	Good Soil Condition
Montay 4	A	14	Moderate Soil Condition
	B	19	Good Soil Condition
	C	16	Good Soil Condition
Montay 5	A	17	Good Soil Condition
	B	22	Good Soil Condition
	C	19	Good Soil Condition
Montay 6	A	11	Moderate Soil Condition
	B	14	Moderate Soil Condition
	C	17	Good Soil Condition
Montay 7	A	22	Good Soil Condition
	B	14	Moderate Soil Condition
	C	13	Moderate Soil Condition
Montay 8	A	15	Good Soil Condition
	B	14	Moderate Soil Condition
	C	9	Moderate Soil Condition
Montay 9	A	11	Moderate Soil Condition
	B	6	Poor Soil Condition
	C	9	Moderate Soil Condition
Montay 10	A	8	Moderate Soil Condition
	B	11	Moderate Soil Condition
	C	8	Moderate Soil Condition

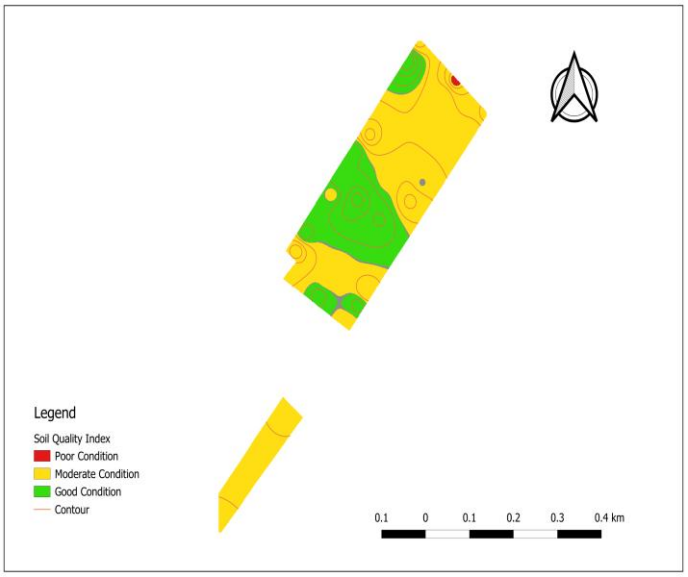

Fig. 11. Soil Quality Index

V. Summary, Conclusions, and Recommendations

The study assessed the soil quality of rice farms with an area of at least 1 ha in Barangay Montay, Datu Piang, Maguindanao del Sur, using visual indicators, including soil structure, soil crusting, earthworm abundance, plant root development, and soil texture. The results revealed variations in soil conditions among the 30 samples. Several sites exhibited good soil structure with friable aggregates, while others showed large, firm clods and moderately well-developed tillage pans. Most samples had moderate soil crusting, although a few exhibited continuous crusts that may restrict water infiltration. Earthworm abundance was generally low, with 29 out of 30 samples containing fewer than four earthworms. Sandy, sandy loam, and silt loam were the predominant soil textures, while loam was observed at Montay 10. The integrated Soil Quality Index classified 11 samples as having good soil condition, 18 as moderate, and one sample, Montay 9B, as poor.

The visual soil assessment showed that soil condition varied among the selected rice farms in Barangay Montay, Datu Piang, Maguindanao del Sur, with most samples classified as having moderate soil condition. Variations in the surface crusting, soil structure, earthworm abundance, plant root development, and soil texture contributed to differences in the overall Soil Quality Index.

The prevalence of moderate soil condition indicates the presence of physical and biological limitations that may affect soil functions, particularly water movement, root penetration, aeration, and biological activity. The occurrence of tillage pans, firm clods, surface crusting, and generally low earthworm abundance suggests localized potential for soil degradation. The combined occurrence of poor soil structure, a developed tillage pan, and continuous surface crusting in Montay 9B exhibited the poorest soil condition.

Finally, the LADA Visual Soil Assessment and integrated Soil Quality Index proved useful in identifying variations in soil condition and potential signs of land degradation among the assessed rice farms. The findings highlight the need for appropriate and sustainable soil management practices to improve soil quality, prevent further degradation, and support the long-term productivity of the rice farming systems in Barangay Montay.

The study further recommends that (1) Part 2 of the LADA-L soil assessment, which involves soil measurements, be included in future assessments; and (2) the assessment be repeated during the dry season to determine whether soil conditions differ significantly from those observed during the rainy season, when the field survey was conducted.

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