

# Suitability Evaluation for Pearl Millet (*Pennisetum Glaucum L.*) and Groundnut (*Arachis Hypogaea L.*) Production in University of Maiduguri Farmland (Dalori Area), Sudan Savanna, Nigeria

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| Article History                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Abstract                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
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| <b>Original Research Article</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | <p><i>This research was carried out in 2023 on the University of Maiduguri teaching and research farmland, situated along the Dalori area in Konduga Local Government Area of Borno State, Northeastern Nigeria. The site lies between latitudes 11°46.758'–11°47.116' N and longitudes 13°12.744'–13°13.188' E. The study aimed to determine how suitable the soils in this area are for cultivating pearl millet and groundnut. To achieve this, both qualitative and quantitative land-suitability assessment methods were used. The qualitative assessment employed the Simple Limitation Method (SLM), while the quantitative evaluation followed the Storie (1978; 2008) parametric approach. A total of 27 soil samples were obtained from six pedons within a single soil-mapping unit (DL), which was later categorized into three phases DL I, DL II, and DL III representing different parts of the study area. Results from the SLM showed that the soils were permanently not suitable (N2) for pearl millet and currently not suitable (N1) for groundnut. The Storie method produced similar ratings, also indicating permanent unsuitability (N2) for millet and current unsuitability (N1) for groundnut. These limitations were mainly linked to poor soil chemical characteristics. To enhance soil quality and crop productivity, the study recommends practices such as adding crop residues and farmyard manure, implementing reduced tillage and mulching, and applying fertilizers at the recommended rates for each crop. Over time, these improvements could shift the soils from unsuitable to suitable classes for both millet and groundnut, thereby promoting sustainable crop production in the area.</i></p> <p><b>Keywords:</b> Soil suitability evaluation, Pearl millet, Groundnut, Simple Limitation Method (SLM) and Storie Index</p> |
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| <b>Published: 22-11-2025</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
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## 1.0 Introduction

Land is among the most essential natural resources available to humanity, and its proper management is vital for sustaining the rising global demand for food, fiber, fodder, and fuel (Fadlalla and Elsheikh, 2016). Choosing crops that match the characteristics of a particular soil type is therefore fundamental, as it enables farmers to increase yields while minimizing environmental degradation (Öztürk, 2017). Sound crop-land use planning relies heavily on well-informed decisions regarding how land and environmental resources should be utilized. In this context, soil information is particularly important because it directly

influences how suitable a given area is for different land uses (Coleman and Galbraith, 2000).

Land suitability describes the process of determining whether a specific land unit is capable of supporting a particular use (Bhandari et al., 2013). The degree of alignment between a crop's ecological requirements and the physical and chemical characteristics of the soil largely dictates how appropriate that land will be for cultivation (Ahmed, 2015). In practice, suitability assessment involves matching the conditions of the land with the needs of the crop (Mathewos et al., 2018). According to FAO (1983), land evaluation seeks to determine the potential

performance of land for various uses. Beyond estimating possible yields, a comprehensive land evaluation also indicates whether a land use is sustainable over the long term (Baja, 2009). For this reason, describing soil attributes in relation to intended land-use options is a crucial component of land-suitability analysis.

Groundnut (*Arachis hypogaea* L.) a legume in the Fabaceae family is a globally cultivated cash crop of considerable economic value. It plays a significant role in the economies of producing nations and serves as a key raw material in the manufacture of food, animal feed, paints, lubricants, insecticides, and several industrial goods (Janila et al., 2013; Variath and Janila, 2017). Pearl millet (*Pennisetum glaucum* L.), a cereal crop belonging to the Poaceae family, is considered one of the earliest domesticated grains. Worldwide, it ranks sixth in importance after maize, wheat, rice, barley, and sorghum (FAO, 2014). As noted by Patel et al. (2015), pearl millet is especially valuable to

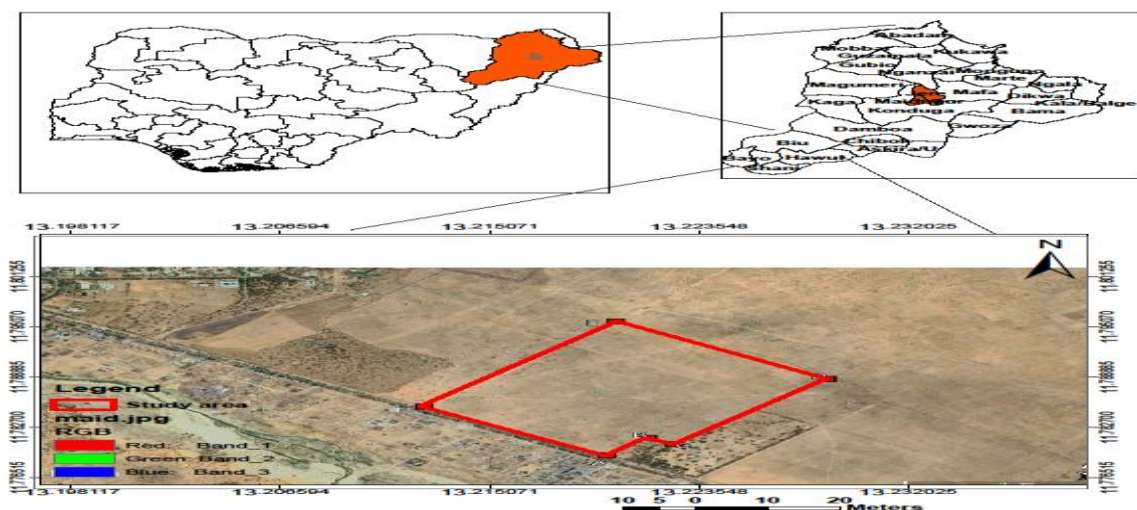
smallholder farmers because it strengthens food security and provides economic opportunities.

In recognition of the importance of these crops, the present study aimed to evaluate the suitability of soils for cultivating pearl millet and groundnut on the University of Maiduguri farmland, located within the Sudan Savanna ecological zone of Nigeria.

## 2.0 Materials and Methods

### 2.1 Study Area

The study was carried out in 2023 on the University of Maiduguri farmland, situated along the Dalori axis in Konduga Local Government Area of Borno State, Northeastern Nigeria (Fig. 1). The research site is positioned between latitudes 11°46.758' and 11°47.116' N and longitudes 13°12.744' and 13°13.188' E. The area covers roughly 168 hectares of land designated for agricultural activities within the university.



**Fig. 1:** Map of the Study Area

### 2.2 Climate and characteristics of the area

According to Ojanuga (2006), the area experiences a dry sub-humid climate characterized by a single rainy season. Average annual temperatures hover around 32°C, while total yearly rainfall is about 660 mm, typically confined to a short period of roughly four months from June to September (NIMET, 2023). The region lies within the Sudan Savanna agro-ecological zone, where humidity rises sharply during the rainy season and falls abruptly once it ends. Relative humidity may reach 100% at night in August but can drop to 20% or even lower during the hottest part of the day in the harmattan period (World Bank, 2023).

The dominant soils in the study area are aeolian sands, which were deposited by wind from the Sahel region (FAO and ICRISAT, 2019). Elevation across the site ranges from 325 to 333 meters above mean sea level, and the terrain is generally flat to gently undulating. Agriculture is the

primary economic activity in the Sudan Savanna (Onwualu, 2009). In the Dalori area, farming primarily focuses on short-duration, drought-tolerant crops such as groundnut (*Arachis hypogaea*), cowpea (*Vigna unguiculata*), sorghum (*Sorghum bicolor*), and millet (*Pennisetum glaucum*). The original vegetation, which was characterized by shrubs, occasional trees, and scattered woodlands, has been rapidly declining due to the combined effects of climate change and human activities. This decline has accelerated land degradation and desertification in the region (Waziri et al., 2009).

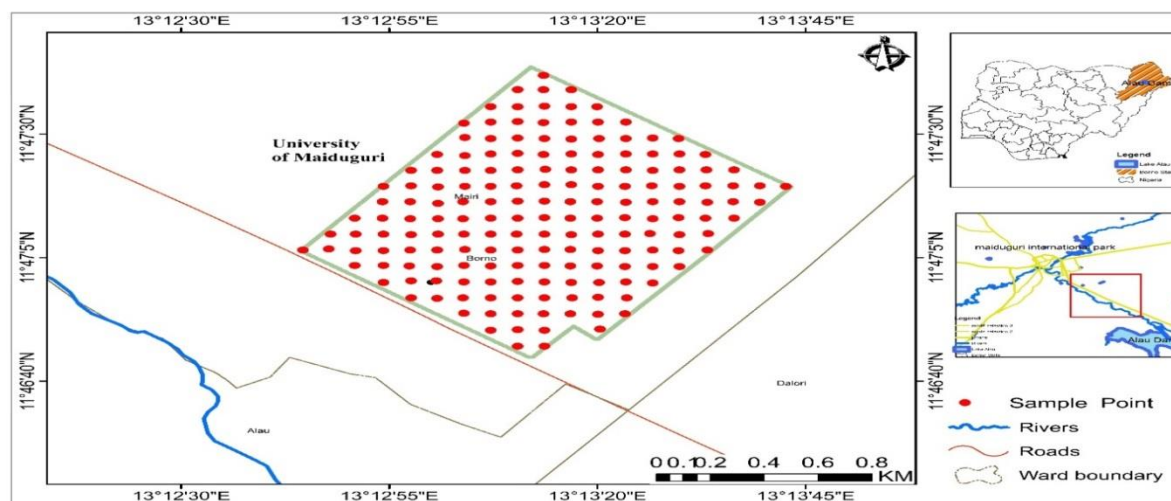
### 2.3 Soil Survey

The soil survey began with a reconnaissance assessment along selected paths across the study area. Key points along the farm boundaries were recorded using a Polarix Navigator GPS. This was followed by a semi-detailed soil survey at a scale of 1:25,000 to identify and map the various

soil types. Soil characteristics were examined at regular intervals of 100 meters along each traverse using auger borings (Fig. 2).

Soil boundaries were delineated based on differences in morphological features, physiographic positions, topography, and color. Soils with similar characteristics were grouped into a single mapping unit, while distinct

types were mapped separately. For each identified soil mapping unit, two representative profile pits were excavated, each approximately 1 m wide, 1.5 m long, and 2 m deep (Fig. 2), with the second pit serving as a duplicate. Bulk soil samples were collected from each horizon for laboratory analysis, and the soil profiles were described in accordance with the guidelines outlined in the Soil Survey Manual (Soil Survey Staff, 2006).



**Fig. 2:** Base Map of the Study Area

## 2.4 Land Suitability Evaluation

The suitability of soils for the selected crops was assessed using the Food and Agriculture Organization (FAO) land evaluation framework (FAO, 2007) along with the FAO guidelines for evaluating land under rain-fed agriculture (FAO, 1984; Rossiter, 1996).

Two complementary evaluation methods were applied:

- Qualitative Non-parametric Approach – Simple Limitation Method (SLM)
- Quantitative Parametric Approach – Storie Index Method

### 2.4.1 Qualitative Non-parametric Approach (Simple Limitation Method)

In this approach, the physical and chemical properties gathered from field observations and laboratory analyses collectively referred to as land qualities or land characteristics were compared with the ecological requirements of millet and groundnut. The comparison was based on the modified crop-suitability criteria for both crops developed by Sys (1985) and later updated by Sys (1993) (Tables 1 and 2).

For each soil series identified in the study area, the final suitability class was determined by the most limiting land characteristic following the procedures outlined by Sys et al. (1993). Only permanent or nearly permanent land attributes—those that cannot be altered without high financial investment—were considered in the evaluation. These include moisture availability, temperature regime, drainage or aeration status, soil depth, nutrient availability, nutrient retention capacity, mechanization potential, erosion risk, and land preparation

conditions. Such characteristics often restrict crop performance when they fall below optimal levels (Fasina and Adeyanju, 2006).

### 2.4.2 Quantitative Parametric Approach (Storie Index Method)

The parametric evaluation method assigns numerical ratings to land characteristics according to the degree of limitation they pose. These ratings typically range from 0 to 100, with higher values indicating more favorable conditions (Sys et al., 1991; Van Ranst and Verdoot, 2005; O'Geen et al., 2008) (Table 3).

**The Storie Index Method considers the following groups of land qualities:**

- Climate (c): mean annual temperature and annual rainfall
- Soil Physical Characteristics (s): texture, effective soil depth, drainage, and slope
- Nutrient Availability (f): soil pH, nitrogen (N), phosphorus (P), potassium (K), organic carbon, and cation exchange capacity (CEC)

As with the qualitative method, the ratings for each soil series were generated by matching crop requirements with the measured land qualities following Sys et al. (1993). After assigning the appropriate numerical scores, the final land or soil index values were computed using the Storie formula:

$$I = A \times \frac{B}{100} \times \frac{C}{100} \times \dots \times n, \text{ where}$$

$I$  = index (%) of suitability,

$A$  = index of the most limiting factor,

$B, C, \dots, n$  = indexes of other factors besides the most limiting (O'geen et al., 2008).

**Table 1:** Land Use Requirements for Millet

| Land qualities/characteristics           | Factor suitability rating |                          |                          |                    |                               |
|------------------------------------------|---------------------------|--------------------------|--------------------------|--------------------|-------------------------------|
|                                          | Highly suitable (S1)      | Moderately suitable (S2) | Marginally suitable (S3) | Not suitable (N1)  | Permanently not suitable (N2) |
| <b>Climate</b>                           |                           |                          |                          |                    |                               |
| Rainfall (mm)                            | 450-500                   | 500-600                  | 600-800                  | 200-250            | <200                          |
| Temperature (°C)                         | 26.70-26.99               | 26.40-26.69              | 26.20-26.39              | 26.10-20.19        | --                            |
| <b>Soil physical characteristics (S)</b> |                           |                          |                          |                    |                               |
| Soil depth (cm)                          | 21-30                     | <u>10-21</u>             | 0-10                     | <10                |                               |
| Soil texture                             | Si, CL, L, SC,            | SL, SCL                  | LS, Lfs                  | Cm, Si Cm, Lc S, F | Cs                            |
| Topography (t) Slope (%)                 | 0-2                       | 2-5                      | 5-8                      | >8                 |                               |
| Drainage                                 | Well drained              | Moderately well drained  | Imperfectly drained      | Poorly drained     |                               |
| <b>Soil fertility status (f)</b>         |                           |                          |                          |                    |                               |
| Ph                                       | 6.5-6.0, 6.5-7.0          | 6.0-5.6, 7.0-7.6         | 5.6-5.4, 7.6-8.0         | 5.4-5.2, 8.0-8.2   | 8.4-14                        |
| Total N (g kg <sup>-1</sup> )            | 0.5-0.1                   | 0.25-0.50                | 0.15-0.25                | 0.05-0.15          | <0.05                         |
| Available P (mg kg <sup>-1</sup> )       | 25-30                     | 18-25                    | <u>10-18</u>             | <u>5-10</u>        | 0-5                           |
| CEC (cmol(+) kg <sup>-1</sup> )          | <u>10-15</u>              | <u>5-10</u>              | 0-5                      | --                 | --                            |
| Base saturation (%)                      | >80                       | 50-80                    | 40-50                    | <40                |                               |
| Organic C (g kg <sup>-1</sup> )          | 1.6-3.0                   | 1.5-0.8                  | 1.0-0.2                  | --                 | --                            |

**Source:** Sys (1993).

Where: Si = Silt, CL = Clay Loam, L = Loam, SC = Sandy Clay, SL = Sandy Loam, SCL = Sandy Clay Loam, LS = Loamy Sand, Lfs = Loamy Fine Sand, Cm = Clay, SiCm = Silty Clay, LcS = Light Clay Soil or Loamy Clay Sand, F = Fine (usually refers to fine-textured soils: silty or clayey), Cs = Coarse Sand / Coarse-textured soil.

**Table 2:** Land Use Requirements for Groundnut

| Land qualities/characteristics           | Factor suitability rating |                          |                          |                  |
|------------------------------------------|---------------------------|--------------------------|--------------------------|------------------|
|                                          | Highly suitable (S1)      | Moderately suitable (S2) | Marginally suitable (S3) | Not suitable (N) |
| <b>Climate</b>                           |                           |                          |                          |                  |
| Rainfall (mm)                            | >700                      | 600-700                  | 500-600                  | <500             |
| Temperature (°C)                         | 22-28                     | 18-22                    | 15-18                    | <15              |
| <b>Soil physical characteristics (S)</b> |                           |                          |                          |                  |
| Soil depth (cm)                          | > 120                     | 75-120                   | 30-75                    | <30              |
| Soil texture                             | SL, SiL, LS               | CL, SiCL                 | S, SC, SiC               | C                |
| Soil Structure                           | Weakly-V.Strong.          | Modera.Develop.          | Modera.Develop.          | Structureless    |
| Topography (t) Slope (%)                 | 0-2                       | 2-5                      | 5-8                      | >8               |
| Drainage                                 | Well drained              | Moderately well drained  | Imperfectly drained      | Poorly drained   |
| <b>Soil fertility status (f)</b>         |                           |                          |                          |                  |
| Ph                                       | 5.8-6.2                   | 5.5-5.7 6.3-6.5          | 5.0-5.4, 6.6-7.0         | <5, > 7          |
| CEC (cmol/ kg)                           | >12                       | 6-12                     | 4-6                      | <64              |
| Exchg. Ca (cmol/ kg)                     | 5-10                      | 3.8-4.9                  | 2.6-3.9                  | <2.6             |
| Exchg. Mg (cmol/ kg)                     | 0.9-1.4                   | 0.6-0.9                  | 0.3-0.59                 | <0.3             |
| Exchg. K (cmol/ kg)                      | 0.3-0.5                   | 0.2-0.29                 | 0.1-0.19                 | <0.1             |
| Base saturation (%)                      | >80                       | 50-80                    | 40-50                    | <40              |
| Organic C (g/ kg)                        | >12                       | 8-12                     | 5-8                      | <5               |
| EC (dSm <sup>-1</sup> )                  | 0-2                       | 2-3                      | 3-4.5                    | >4.5             |
| ESP (%)                                  | 1.0-10                    | 10-15                    | 15-20                    | >20              |

**Source:** FAO (1983).

Where: LS = Loamy Sand, SL = Sandy Loam, CL = Clay loam, SiL = Silt Loam, SiCL = Silt Clay Loam, C-Clay, S = Sand, SC = Sandy Clay.

**Table 3:** Modified Rating of limiting factors of land quality for parametric suitability Evaluation for Millet and Groundnut

| Degree of limitation     | Land Index (ratings) | Land Suitability Class |
|--------------------------|----------------------|------------------------|
| Highly Suitable          | 75 – 100             | S1                     |
| Moderately Suitable      | 50 – 75              | S2                     |
| Marginally Suitable      | 25 – 50              | S3                     |
| Marginally Not Suitable  | 12.5 – 25            | N1                     |
| Permanently Not Suitable | 0 – 12.5             | N2                     |

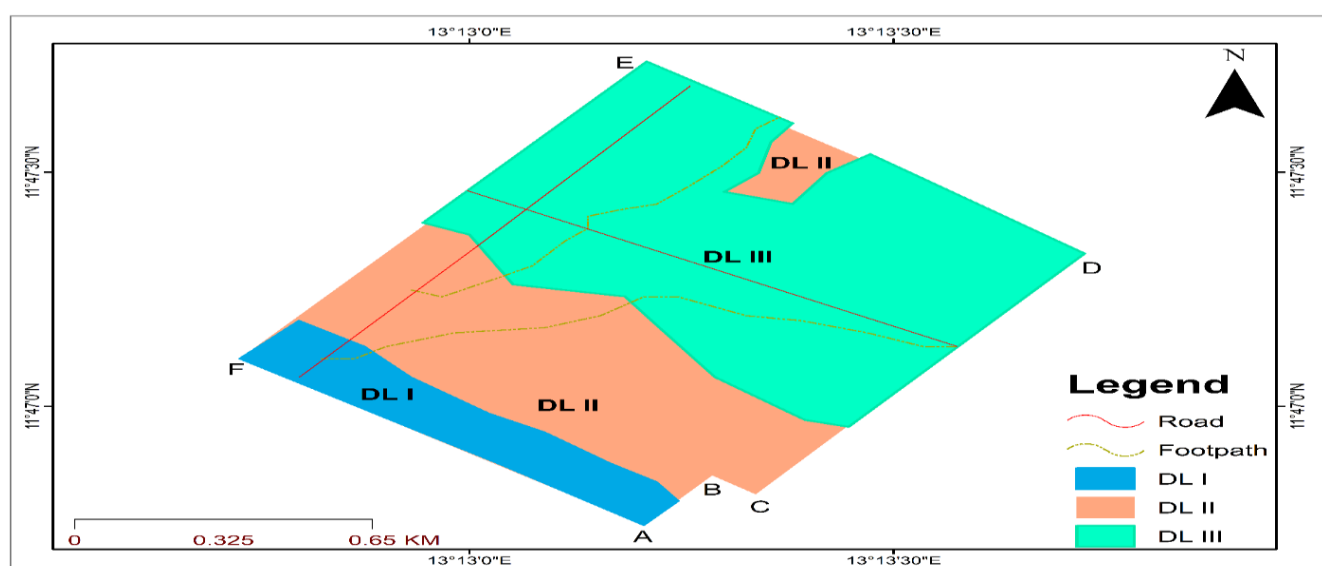
Source: A. Sharififar. 2012

### 3.0 RESULTS AND DISCUSSION

#### 3.1 Extend and Distribution of Soil Unit

The study area was denoted in to one soil unit, Dalori Soil Unit (DL). The soil unit was delineated in to three soil phases. Dalori Phase I: DL I (P1 and P2), Dalori Phase II: DL II (P3 and P4) and Dalori Phase III: DL III (P5 and P6).

Soil phase DL I and DL II were located on the lower part while phase DL III were on the upper part. The physiography of the study site is nearly level plain on 0-2 % slope gradient. Groundwater was not encountered at any profile depth. A total of six (6) pedons were dug and described. The soil map of study area is shown in Fig 1.



**Fig 3:** Study Area showing different Distribution of Soil Phases

#### 3.2.1 Qualitative Land Suitability Evaluation (Simple Limitation Method – SLM)

Table 4 summarizes the land characteristics of the identified soil phases, while Tables 5 and 6 present the corresponding suitability ratings for millet and groundnut cultivation.

##### 3.2.1.1 Climatic Factors

A comparison of the climatic needs of millet and groundnut with the prevailing conditions across the three soil phases (DL I, DL II, and DL III) shows that temperature does not limit the production of either crop. Accordingly, temperature received a highly suitable (S1) rating for both crops. Rainfall, however, affected suitability differently: it was rated moderately suitable (S2) for groundnut but only marginally suitable (S3) for millet. Thus, rainfall emerged as the only climate-related limitation influencing millet production (Tables 5 and 6).

##### 3.2.1.2 Physical Factors

Soils in the study area ranged from sandy loam to sandy clay loam, and this variation in texture posed no major restriction to either millet or groundnut, regardless of slope position. Soil phases DL I (P1 and P2) and DL II (P3) were assessed as highly suitable (S1) for groundnut, while DL II (P4) and DL III (P5 and P6) were rated moderately suitable (S2). For millet, all soil phases were classified as moderately suitable (S2) based on texture.

Slope conditions were uniformly favorable and therefore rated highly suitable (S1) for both crops across all phases. Soil depth showed a similar trend, receiving an S1 rating due to the relatively consistent depth throughout the area. Drainage was also generally good, resulting in a highly suitable (S1) classification for both millet and groundnut (Tables 5 and 6).

### 3.2.1.3 Fertility Status

The fertility status of the soils was generally poor, reflected in low levels of organic carbon, organic matter, total nitrogen, and available phosphorus, consistent with the criteria outlined by Brady and Weil (2012).

Soil pH varied among the phases. For millet, pH was rated highly suitable (S1) in P3 and P4, moderately suitable (S2) in P2 and P6, and not suitable (N1) in P1 and P5. For groundnut, pH was highly suitable (S1) in P4 and P6, marginally suitable (S3) in P3 and P5, and not suitable (N1) in P1 and P2.

Total nitrogen and organic carbon were consistently rated not suitable (N1) for both crops across all soil phases (DL I, DL II, and DL III). Available phosphorus was generally marginally suitable (S3) for millet except in DL II (P3),

where it was rated not suitable (N1). For groundnut, available P tended to be moderately suitable (S2), except for P3, where it was marginally suitable (S3).

CEC ratings also varied by crop and phase. For millet, CEC was classified as permanently not suitable (N2). In contrast, for groundnut, CEC ranged from marginally suitable (S3) to moderately suitable (S2) within DL I (P1). Percent base saturation was uniformly high and therefore considered highly suitable (S1) for both crops throughout all soil phases (Tables 5 and 6).

Overall, the most significant limitations to millet and groundnut production were tied to nutrient deficiencies particularly low nitrogen, organic carbon, and available phosphorus. These fertility constraints represent the primary barriers to improved soil suitability in the study area.

**Table 4: Land Characteristics of the Study Area**

| Land Characterization / Diagnostic Factors  | Soil Units       |                   |                   |                   |                   |                   |
|---------------------------------------------|------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
|                                             | Lower Part       |                   |                   | Upper Part        |                   |                   |
|                                             | ----- DL I ----- |                   |                   | ----- DL II ----- |                   | ---- DL III ----  |
| Climate                                     | PI               | P2                | P3                | P4                | P5                | P6                |
| Rainfall (mm)                               | 660              | 660               | 660               | 660               | 660               | 660               |
| Temperature (°C)                            | 26               | 26                | 26                | 26                | 26                | 26                |
| Soil physical characteristics (S)           |                  |                   |                   |                   |                   |                   |
| Soil depth (cm)                             | 200              | 200               | 200               | 200               | 200               | 200               |
| Soil texture                                | SL               | SL                | SL                | SCL               | SCL               | SCL               |
| Soil structure                              | Weakly-V.Stron.  | Moderate.Develop. | Moderate.Develop. | Moderate.Develop. | Moderate.Develop. | Moderate.Develop. |
| Topography (t) Slope (%)                    | 0-2              | 0-2               | 0-2               | 0-2               | 0-2               | 0-2               |
| Drainage                                    | Well drained     | Well drained      | Well drained      | Well drained      | Well drained      | Well drained      |
| Soil fertility status (f)                   |                  |                   |                   |                   |                   |                   |
| pH in H <sub>2</sub> O                      | 8.12             | 7.5               | 6.69              | 6.25              | 5.39              | 6.24              |
| Exchg. Ca (cmol/ kg)                        | 2.85             | 2.2               | 2.12              | 1.88              | 1.85              | 2.9               |
| Exchg. Mg (cmol/ kg)                        | 3.05             | 3.36              | 3.12              | 2.12              | 3.9               | 3.35              |
| Exchg. K (cmol/ kg)                         | 0.19             | 0.05              | 0.05              | 0.07              | 0.04              | 0.07              |
| CEC (cmol <sub>(+)</sub> kg <sup>-1</sup> ) | 6.31             | 5.63              | 5.31              | 4.11              | 5.83              | 5.51              |
| Base saturation (%)                         | 88.53            | 85.53             | 86.87             | 82.66             | 88.58             | 86.17             |
| Organic C (g kg <sup>-1</sup> )             | 3.3              | 2.2               | 3.8               | 3.9               | 3.6               | 3.7               |
| EC (dSm <sup>-1</sup> )                     | 0.15             | 0.04              | 0.05              | 0.08              | 0.21              | 0.08              |
| ESP (%)                                     | 23               | 2                 | 2                 | 4                 | 4                 | 7                 |

Where: SL = Sandy Loam, SCL = Sandy Clay Loam.

**Table 5: Suitability Evaluation of the Study Area for Millet Using SLM**

| Land Characterization                       | Soil Units       |                   |           |                    |           |           |
|---------------------------------------------|------------------|-------------------|-----------|--------------------|-----------|-----------|
|                                             | Lower Part       |                   |           | Upper Part         |           |           |
|                                             | ----- DL I ----- | ----- DL II ----- |           | ----- DL III ----- |           |           |
| <b>Climate</b>                              | <b>PI</b>        | <b>P2</b>         | <b>P3</b> | <b>P4</b>          | <b>P5</b> | <b>P6</b> |
| Rainfall (mm)                               | S3               | S3                | S3        | S3                 | S3        | S3        |
| Temperature (°C)                            | S1               | S1                | S1        | S1                 | S1        | S1        |
| <b>Soil physical characteristics (S)</b>    |                  |                   |           |                    |           |           |
| Soil depth (cm)                             | S1               | S1                | S1        | S1                 | S1        | S1        |
| Soil texture                                | S2               | S2                | S2        | S2                 | S2        | S2        |
| Topography (t) Slope (%)                    | S1               | S1                | S1        | S1                 | S1        | S1        |
| Drainage                                    | S1               | S1                | S1        | S1                 | S1        | S1        |
| <b>Soil fertility status (f)</b>            |                  |                   |           |                    |           |           |
| pH in H <sub>2</sub> O                      | N1               | S2                | S1        | S1                 | N1        | S2        |
| Total N (g kg <sup>-1</sup> )               | N1               | N1                | N1        | N1                 | N1        | N1        |
| Available P (mg kg <sup>-1</sup> )          | S3               | S3                | N1        | S3                 | S3        | S3        |
| CEC (cmol <sub>(+)</sub> kg <sup>-1</sup> ) | S2               | N2                | N2        | N2                 | N2        | N2        |
| Base saturation (%)                         | S1               | S1                | S1        | S1                 | S1        | S1        |
| Organic C (g kg <sup>-1</sup> )             | N1               | N1                | N1        | N1                 | N1        | N1        |
| Overall Suitability: Current                | N1(f)            | N2(f)             | N2(f)     | N2(f)              | N2(f)     | N2(f)     |
| Potential                                   | S2               | S3                | S3        | S3                 | S3        | S3        |

S1 = highly suitable, S2 = moderately suitable, S3 = marginally suitable, N = Not suitable, Limitations (restrictive features): S = soil characteristics, f = fertility limitation, T = topography, W = wetness/drainage

**Table 6: Suitability Evaluation of the Study Area for Groundnut Using SLM**

| Land Characterization                       | Soil Mapping Unit |                   |           |                    |           |           |
|---------------------------------------------|-------------------|-------------------|-----------|--------------------|-----------|-----------|
|                                             | Lower Part        |                   |           | Upper part         |           |           |
|                                             | ----- DL I -----  | ----- DL II ----- |           | ----- DL III ----- |           |           |
| <b>Climate</b>                              | <b>PI</b>         | <b>P2</b>         | <b>P3</b> | <b>P4</b>          | <b>P5</b> | <b>P6</b> |
| Rainfall (mm)                               | S2                | S2                | S2        | S2                 | S2        | S2        |
| Temperature (°C)                            | S1                | S1                | S1        | S1                 | S1        | S1        |
| <b>Soil physical characteristics (S)</b>    |                   |                   |           |                    |           |           |
| Soil depth (cm)                             | S1                | S1                | S1        | S1                 | S1        | S1        |
| Soil texture                                | S1                | S1                | S1        | S2                 | S2        | S2        |
| Soil Structure                              | S3                | S2                | S2        | S2                 | S2        | S2        |
| Topography (t) Slope (%)                    | S1                | S1                | S1        | S1                 | S1        | S1        |
| Drainage                                    | S1                | S1                | S1        | S1                 | S1        | S1        |
| <b>Soil fertility status (f)</b>            |                   |                   |           |                    |           |           |
| pH in H <sub>2</sub> O                      | N1                | N1                | S3        | S1                 | S3        | S1        |
| Exchg. Ca (cmol/ kg)                        | S3                | S3                | S3        | N1                 | N1        | N1        |
| Exchg. Mg (cmol/ kg)                        | S1                | S1                | S1        | S1                 | S1        | S1        |
| Exchg. K (cmol/ kg)                         | S3                | N1                | N1        | N1                 | N1        | N1        |
| CEC (cmol <sub>(+)</sub> kg <sup>-1</sup> ) | S2                | S3                | S3        | S3                 | S3        | S3        |
| Base saturation (%)                         | S1                | S1                | S1        | S1                 | S1        | S1        |
| Organic C (g kg <sup>-1</sup> )             | N1                | N1                | N1        | N1                 | N1        | N1        |
| EC (dSm <sup>-1</sup> )                     | S1                | S1                | S1        | S1                 | S1        | S1        |
| ESP (%)                                     | N1                | S1                | S1        | S1                 | S1        | S1        |
| Overall Suitability: Current                | N1(f)             | N1(f)             | N1(f)     | N1(f)              | N1(f)     | N1(f)     |
| Potential                                   | S2                | S2                | S2        | S2                 | S2        | S2        |

S1 = highly suitable, S2 = moderately suitable, S3 = marginally suitable, N = Not suitable, Limitations (restrictive features): S = soil characteristics, f = fertility limitation, T = topography, W = wetness/drainage

### 3.2.2 Quantitative Land Suitability Evaluation Based on the Storie Index

The quantitative land suitability assessment was carried out using the Storie Index Method, which evaluates land based on three major groups of characteristics: climatic factors, soil physical characteristics, and soil fertility status. The results are summarized in Tables 7 and 8.

#### Climatic Factors

Climatic suitability was assessed using temperature and rainfall. Temperature posed no limitation, and all soil phases scored *highly suitable* (S1) with a rating of 100% for both millet and groundnut. Rainfall, however, affected the crops differently: millet received a *marginal suitability rating* (S3) of 50%, whereas groundnut was rated *moderately suitable* (S2) with a score of 75%.

#### Soil Physical Characteristics

The physical properties considered under this category include soil depth, texture, slope, and drainage.

- i. Soil depth: Both the lower and upper slope positions had adequate rooting depth and were therefore rated *highly suitable* (S1) at 100% for all soil phases.
- ii. Soil texture: Soil texture ranged from sandy loam to sandy clay loam in phases DL I, DL II, and DL III. According to Storie's rating system where sandy textures score highest and clayey textures lower these textures were rated *moderately suitable* (S2) at 75%.
- iii. Slope: The entire study area had level to gently sloping terrain, leading to a *highly suitable* (S1) rating of 100% for all phases.
- iv. Drainage: All soil phases were well-drained and therefore rated *highly suitable* (S1) at 100%.

#### Fertility Status

Fertility characteristics included soil pH, total nitrogen (N), available phosphorus (P), exchangeable cations (Ca, Mg, K), cation exchange capacity (CEC), organic carbon (OC), and base saturation.

- a. Soil pH:
  - i. DL I: Rated *not suitable* (N1) at 25% and *moderately suitable* (S2) at 75% for millet; *permanently not suitable* (N2) at 12.5% for groundnut.
  - ii. DL II: Rated *highly suitable* (S1) at 100% for millet, while groundnut received *marginal suitability* (S3) at 50% and *highly suitable* (S1) at 100% in some pedons.
  - iii. DL III: Rated *not suitable* (N1) at 25% and *moderately suitable* (S2) at 75% for millet;

*marginally suitable* (S3) at 50% and *highly suitable* (S1) at 100% for groundnut.

- b. Total nitrogen (N): All phases were rated *not suitable* (N1) at 25% for both millet and groundnut.
- c. Organic carbon (OC): Similarly rated *not suitable* (N1) at 25% across all soil phases.
- d. Exchangeable bases:
  - i. Magnesium (Mg): All phases rated *highly suitable* (S1) at 100%.
  - ii. Potassium (K): Most phases rated *not suitable* (N1) at 25%, except P1, which was *marginally suitable* (S3) at 50%.
  - iii. Calcium (Ca): For groundnut, DL I and DL II (P3) were *marginally suitable* (S3) at 50%, while DL II (P4) and DL III were *not suitable* (N1) at 25%.
- e. Cation exchange capacity (CEC):
  - i. DL I: Rated *moderately suitable* (S2) at 75% and *not suitable* (N1) at 25% for millet; *moderately suitable* (S2) at 75% and *marginally suitable* (S3) at 50% for groundnut.
  - ii. DL II: Rated *not suitable* (N1) at 25% for millet and *marginally suitable* (S3) at 50% for groundnut.
  - iii. DL III: Rated *not suitable* (N1) at 25% for millet and *marginally suitable* (S3) at 50% for groundnut.
- f. Base saturation: All soil phases recorded *highly suitable* (S1) ratings of 100%.

#### Overall Suitability Ratings

As shown in Tables 7 and 8, the final Storie Index classifications ranged from *not suitable* (N1) to *permanently not suitable* (N2), primarily due to limitations associated with soil fertility parameters.

The Storie index results demonstrated that:

Fertility was the major limiting factor for both millet and groundnut production in the study area.

All soil phases (DL I, DL II, and DL III) were classified as *permanently not suitable* (N2) for millet under current conditions. However, their *potential suitability* improved to *marginally suitable* (S3) if soil fertility is enhanced through interventions such as the use of farmyard manure.

For groundnut, the soils were rated *currently not suitable* (N1) due to low fertility but could become *moderately suitable* (S2) with improved soil nutrient status.

Overall, the soils were found to be deficient in major macronutrients, particularly nitrogen, phosphorus, and potassium representing the most critical constraints to millet and groundnut production in the study area.

**Table 7: Suitability Class Scores of the Study Area for Millet Using Storie Index**

| Land Characterization                       | Soil Mapping Unit |          |                   |            |                    |          |
|---------------------------------------------|-------------------|----------|-------------------|------------|--------------------|----------|
|                                             | Lower Part        |          |                   | Upper Part |                    |          |
|                                             | ----- DL I -----  |          | ----- DL II ----- |            | ----- DL III ----- |          |
| Climate                                     | PI                | P2       | P3                | PI         | P2                 | P3       |
| Rainfall (mm)                               | S3(50)            | S3(50)   | S3(50)            | S3(50)     | S3(50)             | S3(50)   |
| Temperature (°C)                            | S1(100)           | S1(100)  | S1(100)           | S1(100)    | S1(100)            | S1(100)  |
| Soil physical characteristics (S)           |                   |          |                   |            |                    |          |
| Soil depth (cm)                             | S1(100)           | S1(100)  | S1(100)           | S1(100)    | S1(100)            | S1(100)  |
| Soil texture                                | S2(75)            | S2(75)   | S2(75)            | S2(75)     | S2(75)             | S2(75)   |
| Topography (t) Slope (%)                    | S1(100)           | S1(100)  | S1(100)           | S1(100)    | S1(100)            | S1(100)  |
| Drainage                                    | S1(100)           | S1(100)  | S1(100)           | S1(100)    | S1(100)            | S1(100)  |
| Soil fertility status (f)                   |                   |          |                   |            |                    |          |
| pH in H <sub>2</sub> O                      | N1(25)            | S2(75)   | S1(100)           | S1(100)    | N1(25)             | S2(75)   |
| Total N (g kg <sup>-1</sup> )               | N1(25)            | N1(25)   | N1(25)            | N1(25)     | N1(25)             | N1(25)   |
| Available P (mg kg <sup>-1</sup> )          | S3(50)            | S3(50)   | N1(25)            | S3(50)     | S3(50)             | S3(50)   |
| CEC (cmol <sub>(+)</sub> kg <sup>-1</sup> ) | S2(75)            | N2(12.5) | N2(12.5)          | N2(12.5)   | N2(12.5)           | N2(12.5) |
| Base saturation (%)                         | S1(100)           | S1(100)  | S1(100)           | S1(100)    | S1(100)            | S1(100)  |
| Organic C (g kg <sup>-1</sup> )             | N1(25)            | N1(25)   | N1(25)            | N1(25)     | N1(25)             | N1(25)   |
| Overall Suitability:                        | 0.054             | 0.013    | 0.009             | 0.018      | 0.004              | 0.013    |
| Current                                     | N2                | N2       | N2                | N2         | N2                 | N2       |
| Potential                                   | S3                | S3       | S3                | S3         | S3                 | S3       |

Aggregate suitability scores: S1=100-75, S2=75-50, S3=50-25, N1=25-12.5, N2=12.5-0

**Table 8: Suitability Class Scores of the Study Area for Groundnut Using Storie Index**

| Land Characterization                       | Soil Mapping Unit |         |                   |            |                    |         |
|---------------------------------------------|-------------------|---------|-------------------|------------|--------------------|---------|
|                                             | Lower Part        |         |                   | Upper Part |                    |         |
|                                             | ----- DL I -----  |         | ----- DL II ----- |            | ----- DL III ----- |         |
| Climate                                     | PI                | P2      | P3                | PI         | P2                 | P3      |
| Rainfall (mm)                               | S2(75)            | S2(75)  | S2(75)            | S2(75)     | S2(75)             | S2(75)  |
| Temperature (°C)                            | S1(100)           | S1(100) | S1(100)           | S1(100)    | S1(100)            | S1(100) |
| Soil physical characteristics (S)           |                   |         |                   |            |                    |         |
| Soil depth (cm)                             | S1(100)           | S1(100) | S1(100)           | S1(100)    | S1(100)            | S1(100) |
| Soil texture                                | S1(100)           | S1(100) | S1(100)           | S2(75)     | S2(75)             | S2(75)  |
| Soil Structure                              | S3(50)            | S2(75)  | S2(75)            | S2(75)     | S2(75)             | S2(75)  |
| Topography (t) Slope (%)                    | S1(100)           | S1(100) | S1(100)           | S1(100)    | S1(100)            | S1(100) |
| Drainage                                    | S1(100)           | S1(100) | S1(100)           | S1(100)    | S1(100)            | S1(100) |
| Soil fertility status (f)                   |                   |         |                   |            |                    |         |
| pH in H <sub>2</sub> O                      | N1(25)            | N1(25)  | S3(50)            | S1(100)    | S3(50)             | S1(100) |
| Exchg. Ca (cmol/ kg)                        | S3(50)            | S3(50)  | S3(50)            | N1(25)     | N1(25)             | N1(25)  |
| Exchg. Mg (cmol/ kg)                        | S1(100)           | S1(100) | S1(100)           | S1(100)    | S1(100)            | S1(100) |
| Exchg. K (cmol/ kg)                         | S3(50)            | N1(25)  | N1(25)            | N1(25)     | N1(25)             | N1(25)  |
| CEC (cmol <sub>(+)</sub> kg <sup>-1</sup> ) | S2(75)            | S3(50)  | S3(50)            | S3(50)     | S3(50)             | S3(50)  |
| Base saturation (%)                         | S1(100)           | S1(100) | S1(100)           | S1(100)    | S1(100)            | S1(100) |
| Organic C (g kg <sup>-1</sup> )             | N1(25)            | N1(25)  | N1(25)            | N1(25)     | N1(25)             | N1(25)  |
| EC (dSm <sup>-1</sup> )                     | S1(100)           | S1(100) | S1(100)           | S1(100)    | S1(100)            | S1(100) |
| ESP (%)                                     | N(25)             | S1(100) | S1(100)           | S1(100)    | S1(100)            | S1(100) |
| Overall Suitability:                        | 0.054             | 0.054   | 0.109             | 5.493      | 0.041              | 0.082   |
| Current                                     | N1                | N1      | N1                | N1         | N1                 | N1      |
| Potential                                   | S2                | S2      | S2                | S2         | S2                 | S2      |

Aggregate suitability scores: S1=100-75, S2=75-50, S3=50-25, N1=25-12.5, N2=12.5-0

### 3.3 Soil Suitability for millet and groundnut

The results indicate that the current cropping system does not align well with the inherent qualities of the sampling unit. None of the soil phases showed high suitability for their present land-use type when evaluated using the qualitative land suitability method (SLM). Soil phases DL I, DL II, and DL III were classified as *permanently not suitable* (N2) for millet under current conditions, although their potential suitability improves to *marginally suitable* (S3) with appropriate soil management. Likewise, these phases were rated *not suitable* (N1) for groundnut at present but could attain *moderately suitable* (S2) status if fertility constraints are addressed. Thus, at their existing use level, all soil phases remain unsuitable for both crops.

The quantitative (Storie Index) assessment reflected a similar trend. Soil phases DL I, DL II, and DL III were rated *currently not suitable* (N1) for groundnut, primarily due to low fertility, but could become *moderately suitable* (S2) with improvements in nutrient status. For millet, the same soil phases were classified as *permanently not suitable* (N2) under present conditions but could reach a *marginally suitable* (S3) class with the application of fertility-improving practices such as farmyard manure. Enhancing nutrient levels, particularly N, P, and K properties that are readily amendable, would significantly improve the land's potential for millet and groundnut cultivation.

#### 3.3.1 Suitability Limitations for Millet and Groundnut

Although the study area enjoys generally favorable climatic and topographic conditions including suitable annual temperatures, gentle slopes, and moderate rainfall it still faces notable soil-related constraints. For millet, temperature conditions were classified as highly suitable (S1), whereas rainfall received a marginal suitability rating (S3). The most significant limitations were associated with soil fertility: available phosphorus presented a moderate constraint, while total nitrogen, cation exchange capacity (CEC), and organic carbon were identified as severe limiting factors (Table 6).

A similar pattern was observed for groundnut production. While the climate and soil physical properties were either optimal or close to optimal temperature being highly suitable (S1) and rainfall moderately suitable (S2) soil fertility again emerged as the primary challenge. Available phosphorus and CEC posed moderate limitations, whereas exchangeable potassium (K), exchangeable calcium (Ca), and organic carbon were rated as severe constraints (Table 7).

To improve the productivity of land for both crops, targeted soil fertility enhancement measures are essential. The application of organic amendments such as farmyard manure, compost, and crop residues can substantially

improve nutrient availability. Likewise, introducing irrigation systems would allow dry-season production, making use of the region's high solar radiation and dry climate, which help suppress pests and diseases (Udoh and Ogunkunle, 2012).

### 4.0 Conclusion

This study demonstrates that, according to the qualitative land suitability assessment, the soils of the Dalori area are permanently unsuitable (N2) for millet cultivation and currently unsuitable (N1) for groundnut. The quantitative Storie Index evaluation supports these findings, also classifying the soils as permanently unsuitable (N2) for millet and currently unsuitable (N1) for groundnut. These outcomes are predominantly linked to poor soil fertility.

Nevertheless, land productivity can be improved through appropriate soil management practices such as incorporating crop residues and farmyard manure, adopting reduced tillage methods, implementing contour ridging, and applying the recommended fertilizer rates for each crop. These interventions can enhance soil nutrient levels and progressively shift the land into more suitable classes, supporting sustainable millet and groundnut production in the future.

### 5.0 Recommendations

Given that low soil fertility is the major limitation to sustainable crop production in the study area, management practices that enhance soil nutrients should be emphasized. These include returning crop residues to the soil, applying organic manures, and adopting soil conservation practices to address physical and chemical constraints. Additionally, it is recommended that other crops commonly grown in the Dalori area be evaluated to determine their suitability under the prevailing soil conditions.

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