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ASSESSMENT OF SOIL NUTRIENT VARIABILITY IN LOW-INPUT PROSO AND FOXTAIL MILLET CULTIVATIONS IN SRI LANKA

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Millets are gluten-free, nutrient-rich cereals, offering a sustainable solution to global hunger due to their climate resilience and low-input adaptability. In Sri Lanka, proso (*Panicum miliaceum*) and foxtail (*Setaria italica*) millets are mainly grown in chena cultivations in the Low Country Dry Zone, with potential expansion to marginal areas. As soil nutrient data in millet-growing regions remain limited, this study assessed the spatial variability of key soil nutrients across proso and foxtail millet chena cultivations. Soil samples were collected from chena cultivations, after land preparation, using a composite sampling by collecting five random sub-samples in each site, from Dabana, Siyabalanduwa, Thanamalwila, Ampara, Sooriyawewa, Angunakolawewa, Weheragala, Ethimale, and Jaffna. Available nitrogen (N), phosphorus (P), exchangeable potassium (K), organic matter content (OM), pH, and electrical conductivity (EC) were measured and analyzed using R Studio 4.2.1. Available N, P, and K ranged from 91-238 ppm, 5.3-25.7 ppm and 53.9-386.8 ppm, respectively. OM ranged from 0.84%-3.74%, showing a moderately positive correlation with available N ($r=0.51$). Soil pH (4.7-7.9) and EC (0.014-0.143 dS/m) were generally within the tolerance range for millet crops. High levels of N, P, K without fertilization, may be attributed to crop rotation in chena lands, intermittent cultivation of legumes such as groundnut, the incorporation of groundnut residues during land preparation and other traditional farming practices that collectively enhance soil fertility and soil health. However, 40% of sites exhibited suboptimal P levels (<12 ppm), potentially limiting yield in P-sensitive millets like foxtail millet. Principal component analysis revealed that the first two components explained 65.1% of the total variance in soil nutrient data, with OM and N showing strong alignment. Cluster analysis identified three distinct sites, highlighting significant spatial heterogeneity in Jaffna, Sooriyawewa and Dabana compared to other areas. This national soil assessment reveals fertility variation across millet-growing areas, supporting site-specific nutrient management. Replicated multi-season sampling is needed to capture temporal nutrient changes and validate results.

Keywords: low-input agriculture, millet, soil nutrients, spatial analysis, Sri Lanka

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INTRODUCTION

Millets are gluten-free, nutrient-rich cereals in Poaceae family with medicinal and ethnobotanical value, offering a sustainable solution to global hunger due to their climate resilience and ability to thrive in low-input farming. In Sri Lanka, proso millet (*Panicum miliaceum*) and foxtail millet (*Setaria italica*) are cultivated primarily in chena cultivations in Low Country Dry Zone, with potential expansion towards marginal lands. Millets are generally self-pollinated crops, where many species exhibit polyploidy and are adaptive for high food production due to the C4 photosynthetic pathway (Vivitha and Vijayalakshmi, 2015). Their inherent resilience to drought positions them as unique crops for global food insecurity. Millets are known as “The Crop of Future” due to their ability to survive under low-input agricultural strategies especially in irrigation and fertilization (Saxena *et al.*, 2018). In Sri Lanka, millets such as *Panicum miliaceum* (proso millet) and *Setaria italica* (foxtail millet) are primarily cultivated in arid and semi-arid regions. Despite their adaptability, there remains limited empirical data on the soil fertility status of lands currently or potentially under millet cultivation. This lack of data hinders the development of targeted nutrient management strategies. Therefore, this study aims to evaluate the spatial variability of key soil nutrients in low-input millet cultivation areas across diverse agroecological regions in Sri Lanka.

METHODOLOGY

Experimental site

The experiments were conducted in the department of biotechnology, faculty of agriculture and plantation management, wayamba university of sri lanka (wusl) from january to june 2025.

Sample collection

Soil sampling was conducted in chena cultivations after land preparation, Dabana, Siyabalanduwa, Thanamalwila, Ampara, Sooriyawewa, Angunakolawewa, Weheragala, Ethimale, and Jaffna representing nine different agroecological regions by exploring eight provinces (Northern, North Western, North Central, Eastern, Central, Uva, Sabaragamuwa, and Southern) in Sri Lanka. A composite sampling method was conducted at each site, wherein five sub-samples were collected randomly using a zig-zag pattern across each millet field (ranging from 2 to 5 acres) and combined to form a representative sample. Samples were taken from the topsoil layer (0–20 cm).

Assessment of soil parameters

Key soil parameters were measured, including available nitrogen (N), available phosphorus (P), exchangeable potassium (K), organic matter content (OM), pH, and electrical conductivity (EC) using standard soil testing procedures. Available nitrogen was analyzed using the KCl extraction method (Keeney & Nelson, 1982), while available phosphorus was determined by the Olsen method (Olsen, 1954). Exchangeable potassium was extracted using 1N ammonium acetate (Hanway & Heidel, 1952). Organic matter content was assessed through the Walkley-Black wet oxidation method (Walkley & Black, 1934). Soil pH was measured in a 1:1 soil-to-water ratio**,** and EC in a 1:5 ratio (Rhoades, 1996).

Data analysis

Data were statistically analyzed using R Studio 4.2.1 version. Principal Component Analysis (PCA) and k-means clustering were applied to identify spatial patterns and group sites based on nutrient profiles. Pearson correlation was used to evaluate relationships among parameters.

RESULTS AND DISCUSSION

The analysis revealed a wide range of soil fertility across the surveyed sites. Available nitrogen content ranged from 91 to 238 ppm; phosphorus ranged from 5.3 to 25.7 ppm; and potassium ranged from 53.9 to 386.8 ppm. Organic matter content varied between 0.84% and 3.74%, showing a moderate positive correlation with available nitrogen (Correlation Coefficient (r) 0.51), suggesting that OM is a key driver of nitrogen availability in these soils (Figure 1). The measured soil pH ranged from 4.7 to 7.9, while EC values ranged from 0.014 to 0.143 dS/m, both generally falling within the tolerance thresholds for millet crops. EC is moderately affected for N content of soil (Figure 1). Higher levels of N, P, and K without fertilization, may be attributed to crop rotation in chena lands, intermittent cultivation of legumes such as groundnut, the incorporation of groundnut residues during land preparation and other

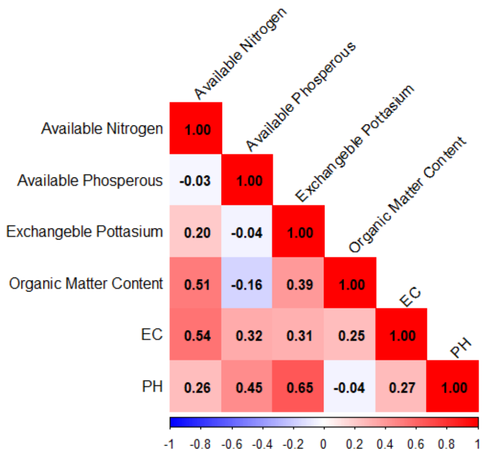

Figure 1: Correlation of soil parameters assessed in millet growing regions

traditional farming practices that collectively enhance soil fertility and soil health. In addition, 40% of the sampled locations exhibited phosphorus levels below 12 ppm, indicating a potential nutrient limitation for P-sensitive millet varieties such as *Setaria italica* (Foxtail Millet).

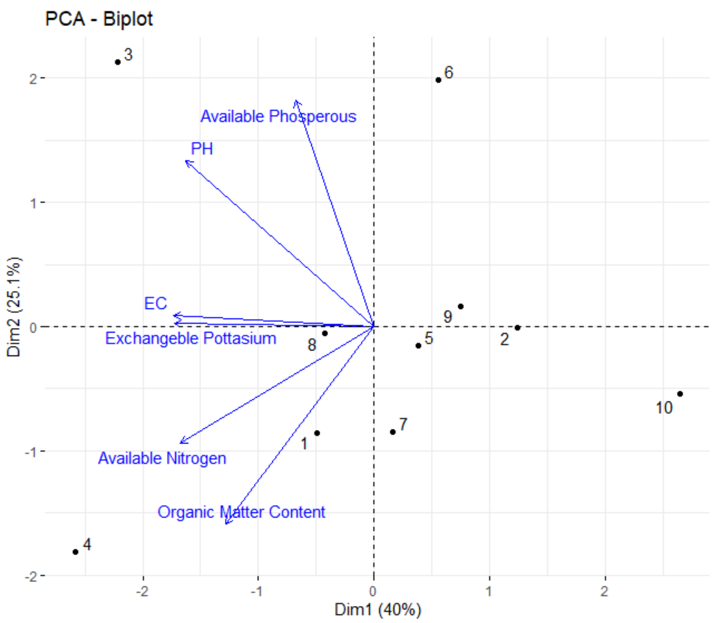

Figure 2: Principle component analysis (PCA) bi plot

EC – Electrical conductivity

PCA reduced the multivariate dataset into two main components (Dim1 = 40%, Dim2 = 25.1%), which together explained 65.1% of the total variance. Variables such as OM and available N were closely aligned, whereas phosphorus and pH loaded distinctly, indicating their unique influence on soil fertility dynamics (Figure 2). Cluster analysis grouped the sampling sites into three distinct clusters, with unique nutrient profiles observed in regions such as Jaffna, Sooriyawewa, and Dabana (Figure 3). These outlier clusters reflect considerable spatial heterogeneity, emphasizing the need for site-specific nutrient interventions. According to the on-site farmer discussions, millet cultivation uses low input soils with minimum irrigation. Hence, these results can be used to improve a species-specific soil for millet cultivation by adjusting the nutrient requirement of the crop. These results provide a deeper understanding on soil variability and its implications for millet productivity.

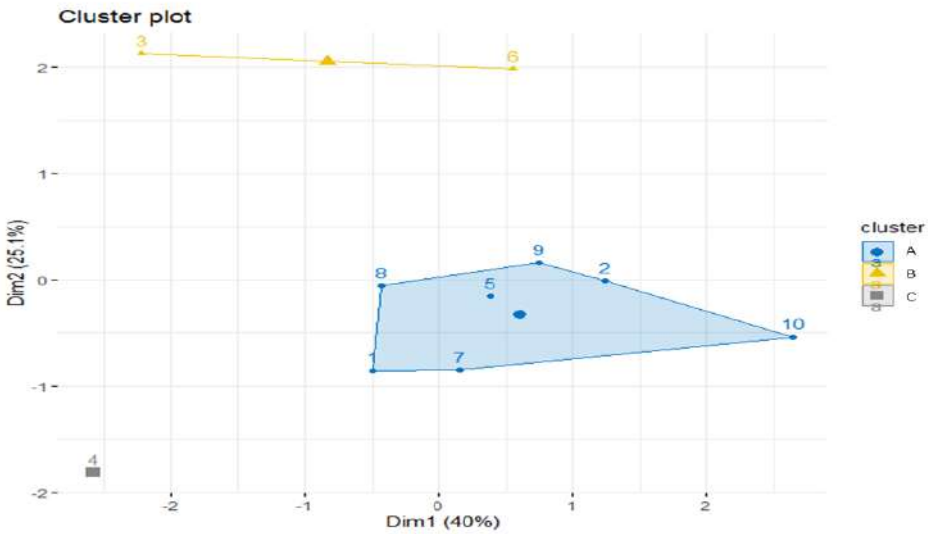

Figure 3: Cluster plot of soil samples according to collected locations

1- Siyambalanduwa, 2- Ampara, 3- Jaffna, 4- Dabana, 5- Thanamalwila, 6- Sooriyawewa, 7 Angunakolawewa, 8- Weheragala, 9- Ethimale, 10- WUSL

CONCLUSIONS/ RECOMMENDATIONS

This first national-scale assessment of millet-growing soils in Sri Lanka reveals significant spatial heterogeneity in soil fertility parameters. While most areas are suitable for low-input millet cultivation, the widespread P deficiency in several regions suggests the need for targeted phosphorus management, particularly for foxtail millet. Organic matter enhancement practices may also improve nitrogen availability. These findings support the development of regionally adapted nutrient recommendations and low-input management strategies. Policymakers and agricultural extension services can leverage these insights to promote sustainable millet expansion in underutilized marginal lands. It is recommended to continue the study with replicated sampling across multiple seasons to capture temporal variation in soil nutrients and strengthen the robustness of findings.

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