Policy Research Journal
ISSN (E): 3006-7030 ISSN (P) : 3006-7022 Volume 3, Issue 2, 2025

NUTRIENT DYNAMICS AND DRY AGGREGATE STABILITY IMPACT ON SOIL CHARACTERISTICS IN THE DRY ENVIRONMENT OF BALOCHISTAN

Shabir Ahmed[1], Shahmir Ali Kalhoro[*2], Punhoon Khan Korai[3], Ammar Rasheed[4], Muhammad Abuzar Jaffar[5], Abdul Hafeez Mastoi[6], Iftakhar Ahmed[7], Muhammad Tahir[8], Aidah Baloch[9], Suhbat Khan[10], Usama Rasheed[11], Hakeem Ullah[12], Muneer Ahmed Rodeni[13], Najeeb Ullah[14]

[1,10]*Department of Agriculture Extension, Quetta, Balochistan, Pakistan*
[*2, 3, 4, 12, 13] *Department of Soil Science, Faculty of Agriculture, LUAWMS*
[5, 14]*Department of Horticulture, Faculty of Agriculture, LUAWMS*
[6]*Department of Entomology, Faculty of Agriculture, LUAWMS*
[7]*Department of Economics, Faculty of Management and Social Sciences, LUAWMS*
[8]*Department of Agriculture Research Institute, Quetta, Balochistan, Pakistan*
[9]*College of Fisheries, Ocean University of China, Qingdao 266003, China*
[10]*Department of Business Management, Faculty of Management and Social Sciences, LUAWMS*

[*2]shahmirali@luawms.edu.pk

DOI: https://doi.org/10.5281/zenodo.14953831

Keywords
Dry Aggregate Stability, MWD, N, P And Ca, Mg.

Article History
Received on 07 January 2025
Accepted on 07 February 2025
Published on 24 February 2025

Corresponding Author: *

Abstract
For reducing soil losses and improving soil quality, especially in arid and semiarid regions, soil aggregate stability is a crucial metric, the main purpose of this study was to compare the differences in soil aggregates between two crop cultivations. This study aimed to evaluate the differences in aggregates among two different crop cultivations (maize and mustard). Dry sieving techniques were used to estimate macro and micro aggregate stability. Higher percentages of macro-aggregate were detected in mustard crop cultivation at 56.56% and 52.53% at soil depths of 0-10 and 10-20 cm, respectively. Compared to subsoil and maize crop cultivations, mustard crops had higher mean weight and geometric mean diameter of macro and micro aggregates at surface soil layers, at 3.87 and 1.99, respectively. The formation and stability of macro and micro-aggregates were positively correlated to soil organic matter concentration, total N, available P, and available K. Mustard farming produced more soil organic matter than maize cultivation in the 0-10 cm soil layer. The correlation matrix of numerous soil indicators, such as nitrogen, phosphorus, potassium concentration, and aggregate stability, demonstrated a positive and significant ($p<0.05$) relationship between mean weight diameter, geometric diameter, and soil organic matter content and a negative association was observed among the micro aggregate. In conclusion, crop cultivation type influenced soil aggregation and size fraction distribution; small fractions of aggregates assorted with fresh organic matter to generate large fractions and higher soil organic matter concentrations were tightly connected with macro-aggregate development. Thus, converting farms to forest and grassland could

improve aggregate stability and reduce soil disturbances in dry and semiarid regions with high erosion risk.

INTRODUCTION

A major interest has recently been created in estimating soil's physic-chemical and biological properties regarding crop production. The degradation of cultivated land is a critical issue worldwide, mostly in developing countries such as Pakistan. Rapid deterioration raised several environmental problems, particularly in arid and semiarid regions of the world. The decline of organic matter and nutrient contents commonly occurred because of unceasing cropping patterns. Agriculture is the backbone of Pakistan's economy and shares 14% of the GDP, and 42% of employment is directly or indirectly involved in agriculture (Ababaki et al., 2024; Ahmed et al., 2024). Balochistan province covers 347,190 sq KM of the area of Pakistan, and the province is divided into 36 districts, Awaran occupied the 3rd position by area 29 51000 ha, with 21,518 ha of cultivated land, though the arable land of the district is 71,520 ha, and available arable potential cropping is only 26,213ha. Nitrogen, phosphorus, and potassium are more important nutrients for crop yield, fertility, and soil health than calcium, magnesium, and sulfur. Fertility is the soil's ability to supply nutrients at suitable levels. Understanding soil's complex interactions of physical, chemical, and biological variables is critical for improving health and fostering agricultural sustainability (Ren et al., 2016; Mengal et al., 2024). Soil health is crucial to healthy agrarian ecosystems, influencing crop growth, nutrient availability, and environmental balance. Proteins and nucleic acids, key components of plant tissues, mostly comprise nitrogen and phosphorus. Nitrogen promotes plant vegetative growth, while phosphorus produces healthy blooms, buds, roots, and fruits. While potassium benefits the plant's sustainability and health, it is mostly involved in fruit development and ripening. Generally, K influences harvested crop yield quality (Muhammad et al., 2014). Furthermore, for optimal crop plant growth, organic or inorganic fertilizers should provide a suitable number of main nutrients. Soil organic carbon (SOC) is an active part of terrestrial systems and the biosphere (Kalhoro et al., 2019). Organic manure improves soil fertility and impacts soil structure, texture, aeration, and organic carbon stock. SOC is important in increasing crop output and lowering greenhouse gas emissions. Like other soil qualities, SOC levels vary due to active interactions between parent material, climate, and geological history at the regional and continental scales (Shang et al., 2015). Furthermore, landscape features such as slope, aspect, elevation, and land use may significantly impact SOC content in places with homogeneous parent material and a single climate regime (Lal, 2009). Crop and soil management practices, such as crop species and crop rotation, tillage applications, fertilizer rates, manure applications, pesticide use, irrigation and drainage methods and availability, and soil and water conservation, all impact SOC content in cropland. These strategies regulate SOC input from crop residues, organic amendments, and SOC output through gas decomposition and movement into aquatic environments via leaching, runoff, and erosion (Turner & Lambert, 2000). Conventional tillage enhances aeration and breaks aggregate, exposing physically protected SOM to microbial attack and promoting soil loss through erosion (Kalhoro et al., 2018; Reynolds, 2009; Kubar et al., 2021). The features of SOC may be useful in developing and evaluating process models and monitoring the impact of land use regimes and climate change on soil carbon reserves. SOM serves as the foundation for soil dynamic behavior. It supports healthy crop supply supplies for microbes and other soil organisms while also regulating the flow of water, air, and nutrients to plants (Bottinelli et al., 2015). SOM can contain more than half of a crop's nitrogen and a quarter of its phosphorus requirements, greatly impacting fertilizer requirements. The total amount and kind of SOM varies by soil, land use system, and plant community. This is critical for both creating SOM and reaping the benefits of its degradation, such as nutrient turnover, aggregate formation, and water storage (Zhao et al., 2014; Franzluebbers, 2010). As a result, the primary goal was to quantify the impact of nutrient dynamic, organic carbon, and soil hydraulic characteristics (dry stable aggregate) on the various cultivated crops in the aware district of Balochistan.

MATERIALS AND METHODS

The presented study was conducted in Korak of division kalat. The district of Korak is located in the south of Balochistan in the Kalat division, with 25^0-03′ to 29^0-22′ north latitudes and 64^0-04′ to 66^0-15′ east longitudes. The study area is famous for the cultivation of onion, melon, barely wheat, sorghum, and fruits. The annual average temperature ranged between 17^0C to 39^0C in winter and summer, with high-speed windstorms commonly occurring from May to July, while an average annual rainfall was 18.93 mm GOP in 2023.

Experimental design and crop management: In 2022-2023, the presented study was organized to estimate the impact of different crop cultivation (mustard and maize) on nutrient dynamics and related soil properties, particularly on soil dry stable aggregates within different size fractions. The main objective of this study was to compare the nutrient dynamics with irrigated and non-irrigated traditionally cultivated field crops and their impact on soil hydraulic properties. Soil core samples were collected in triplicate from each field at 0-10 and 10-20 cm intervals.

Data collection and soil sample processing: before conducting the present proposed study, 2-3 visits were organized to select the field for the present research study. Collected soil and plant samples were packed in the labeled polyethylene bags and transported to the laboratory for further soil and plant analysis to estimate the impact of organic and inorganic fertilization on nutrient dynamics such as nitrogen, phosphorous, potassium, calcium and magnesium, and macro-aggregate (>0.5mm and 2-5mm in diameter aggregates), micro-aggregate (1-2mm, 0.5-1mm, 0.5-0.25mm and <0.25mm in diameter) of dry soil sample. Initially, all type of roots and dead plant material was separated from soil samples, sieved through 0.2mm, and prepared the 1:20 (soil: water) for the analysis of EC (dSm^{-1}), pH, soil organic matter (%), available potassium, available phosphorous, total nitrogen, exchangeable calcium and magnesium (mg/kg) followed by international methodology (Jackson, 2005).

Soil sampling process for aggregate stability

Dry aggregate stability, macro-aggregate, micro-aggregate, mean weight diameter (MWD), and geometric mean diameter (GMD) randomly core soil samples were collected by using a stainless steel cutting ring (20X12.5X6cm of length, width, and height) within triplicates separately from each allocated field of research study areas at both 0-10 cm and 10-20 cm of the soil layers. Collected soil samples were brought to the laboratory for additional investigation; initially, all plant materials were collected. The cleaned soil sample was placed on top of the sieve analyzer (>5mm, 5-2mm, 2-1mm, 1-0.5mm, and 0.5-0.25mm sieves) to determine the dry aggregate stability. Each sample was separately placed on the top of the sieve (>5 mm), and the fixed sieve analyzer rotated at 270 rpm for 2-3 minutes. Sieved samples were weighed on an electrical balance, and the remaining weight of >5mm, 5-2mm for macro-aggregate, and 2-1mm, 1-0.5mm, and 0.5-0.25mm for micro-aggregate were calculated, as well as aggregate stability, aggregate silt+clay (ASC%), clay dispersion index (CDI%), clay flocculation index (CFI%), and dispersion ratio (DR%) were calculated Bouyoucos hydrometer Jackson, 2005; Oades, 1984.

$$\text{ASC} = \%\text{silt} + \text{clay (calgon)} - \%\text{silt} + \text{clay (water)} \quad (1)$$

$$\text{DR} \; \frac{\%\text{silt+clay (dispersed water)}}{\%\text{silt+ clay (dispersed calgon)}} \text{ X } 100 \quad (2)$$

$$\text{CDI} = \frac{\%\text{clay (dispersed water)}}{\%\text{clay (dispersed calgon)}} \text{ X } 100 \quad (3)$$

$$\text{CFI} = \frac{\%\text{clay (dispersed calgon)} - \%\text{clay(dispersed water)}}{\%\text{clay (dispersed calgon)}} \text{ X } 100 \quad (4)$$

$$\text{MWD} = \sum_{i=1}^{n} \text{XWi} \quad (5)$$

MWD = mean weight diameter, where X is the mean diameter of the aggregates remaining on the sieve, Wi is the ratio of the persistent aggregate weight on the sieve to the overall sample weight, and n is the total number of sieves.

$$\text{GMD} = \exp\left(\frac{\sum_{i=1}^{n} \text{Wilog Xi}}{\sum_{i=1}^{n} \text{Xi}}\right) \quad (6)$$

Geometric mean weight diameter, where Wi is the total dry weight of the aggregates, n is the number of sieves, and Xi is the mean diameter of aggregates over each sieve size (Six et al., 2000).

Statistical analysis

One-way (ANOVA) analysis of variance was carried out to estimate the significant difference among the crop cultivations and soil properties (Gomes, 1984). Significantly differences among the crop cultivation and soil properties were calculated by least significant difference (LSD) with a 5% probability level by using MS-Excel and Stat.

RESULTS AND DISCUSSIONS

Soil Characteristics before and after harvesting

The analysis results of soil EC (dSm^{-1}), pH, and textural class of two different cultivated lands are presented in (Table 1). Results showed a non-significant difference among the crop cultivations, and in both soil layers, the soil was sandy loam to silt loam in texture, medium in alkaline, and non-saline. The mean maximum of soil EC 0.53 dSm^{-1} and 0.46 dSm^{-1}, 0.28 dSm^{-1}, 0.25 dSm^{-1} of maize and mustard crop cultivation at 0-10 and 10-20cm of depths, respectively, and pH ranged between 8.0 to 8.1 at both crop cultivations and both soil layers. Mean minimum EC (dSm^{-1}) and pH were recorded at 0.25 dSm^{-1} and 7.9 in maize crop cultivation at 10-20cm of soil depth (Table 1). It confirmed that the texture of the study area was not affected by land use and showed the homogeneity in processes.

Cultivated Crop	Soil Properties			
	pH	EC (dSm^{-1})	SOM (%)	Textural class
0 – 15 cm soil depth				
Mustard (Brassica rapa subsp)	8	0.46	0.81	23% Sand, 62% silt, and 16% clay
Maize (Zea mays L)	7.8	0.53	0.42	31% Sand, 61% silt, and 8% clay
15 – 30 cm soil depth				
Mustard (Brassica rapa subsp)	7.9	0.28	0.795	30% Sand, 59% silt, and 11% clay
Maize (Zea mays L)	7.7	0.25	0.295	24% Sand, 58% silt, and 18% clay

Table 1. Basic soil characteristics of the research areas.

Note: Soil characteristics (EC, pH, organic matter, and texture) are presented in triplicate with standard error (±). Lowercase letters (a, b, and c) indicate significant differences ($p<0.05$) between crop cultivations and soil layers at 0-10cm and 10-20cm.

Impact of soil Organic matter and nutrients in the arid climate

Table 2 presented the analysis results of soil organic matter; results showed that the mean maximum of organic matter of 1.09% was recorded in mustard cultivation at 0-10 cm of the soil layer, while at 10-20cm 0.81% was recorded (Table 2), whereas the mean minimum among the crop and the soil layers was 0.29% recorded in maize cultivation, overall the trend was 1.09%, 0.755%, 0.99%, 0.69%, 0.81%, 0.42%, 0.795%, and 0.295% at both soil layers and both crop cultivation mustard and maize respectively (Table 2). The analysis results of nitrogen (N), phosphorous (P), and potassium (K) are presented in (Figure 1). Results showed a significant difference among the crop cultivation and soil layers, at both soil layers, mean maximums of N, P, and K were 0.51$mgkg^{-1}$, 0.9%, 1.97%, 0.155$mgkg^{-1}$, 0.64%, and 1.47% at 0-10 cm of the soil layer, whereas; the mean minimum were 0.06$mgkg^{-1}$, 0.45%, and 1.27% N, P, and K at 10-20 cm of soil layer of maize cultivation (Figure 1). The results indicated significant differences among the crop cultivations and differences within soil layers (Figure 1). Additionally, the analysis results of calcium and magnesium indicated the adequate available calcium and magnesium at both soil layers and both crop cultivations, mean maximum of available calcium and magnesium was recorded in 273.5 $mgkg^{-1}$ and 708.5 $mgkg^{-1}$ in mustard cultivation (Figure 1), whereas mean minimum 263.5 $mgkg^{-1}$ and 647 $mgkg^{-1}$ was recorded in maize cultivation at 10-20 cm of soil layer (Figure 1). The available soil nutrient content and soil organic matter differed significantly ($p<0.05$) between crop farming and within soil depth.

ISSN (E): 3006-7030 ISSN (P) : 3006-7022 Volume 3, Issue 2, 2025

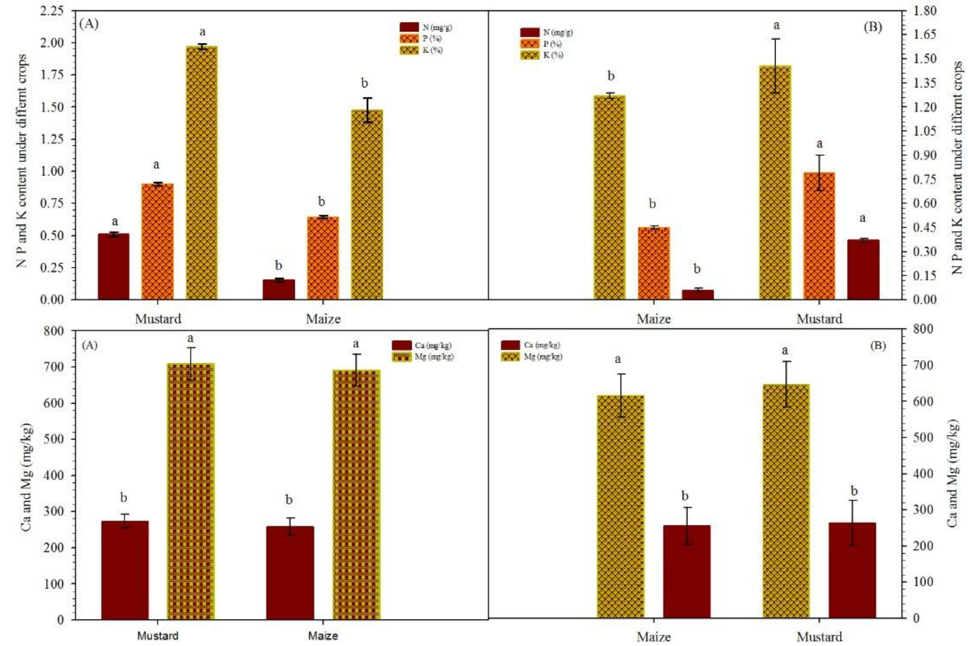

Figure 1: shows the average of nitrogen mg/kg (N), phosphorus % (P), potassium % (K), Ca (Calcium), and Mg (Magnesium) in the soil of maize and mustard in triplicate with standard error (±) at both soil layers A 0-10cm and B 10-20cm, are considerably varied ($p<0.05$) according to the different lowercase letters (a, b, and c)

Impact of dry Aggregate Stability on soil Properties

The analysis results of aggregate stability of two different crop cultivation are presented in (Figure 2). The analysis results of dry aggregate stability of two different crop cultivations are presented at both soil layers for ASC, CDI, CFI, and DR (%) were 20.96, 23.76, 71.65, and 14.33 for mustard and 19.53, 29.58, 66.75, and 20.43 of maize cultivations at 0-10cm of soil layer respectively. Whereas at 10-20 cm of both crop cultivations ASC, CDI, CFI, and DR (%) were recorded as 22.56, 24.74, 76.49, 24.11, 26.1, 20.29, 76.2, and 17.57 respectively of both crop mustard and maize cultivation (Figure 2), likewise; maize recorded greater CDI, and lower ASC and CFI (%), indicating the limited soil aggregation at surface soil layer compared to sub-surface, while; at subsurface soil layer mean maximum of ASC and CFI (%) were recorded in maize compared to mustard crop cultivations (Figure 2). Overall, the observed ASC, CDI, CFI, and DR (%) of crops at both soil layers were significantly different between crop cultivations but non-significant within soil depth (Figure 2).

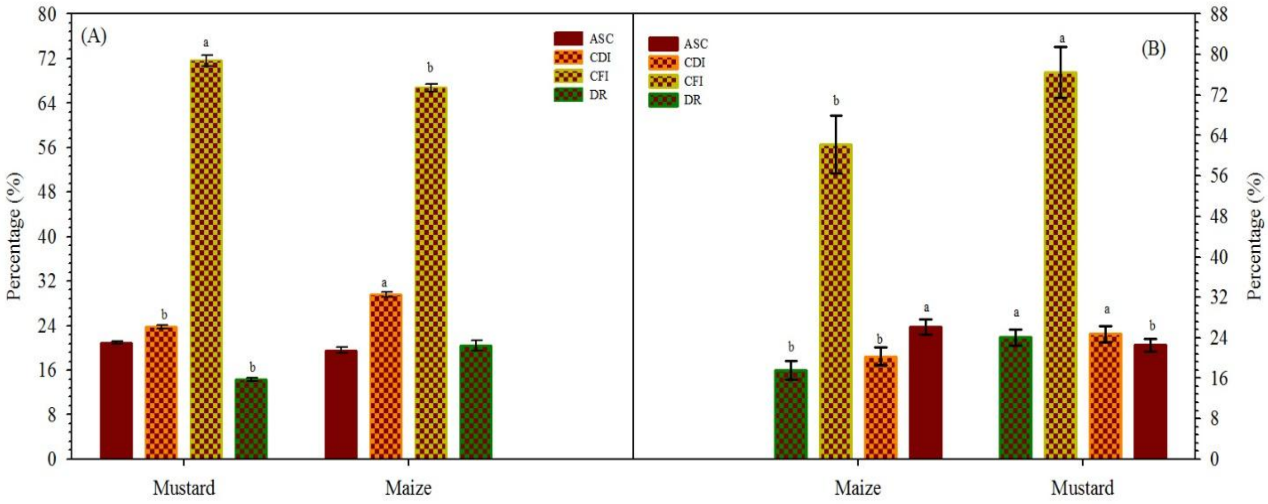

Figure 2: The triplicate mean values with standard errors (±) of ASC (aggregate silt+clay), CDI (clay dispersion index), CFI (clay flocculation index), and DR (dispersion ratio) % in maize and mustard at 0-10cm and 10-20cm soil layers, the different alphabet (a, b, and c) indicated significantly different ($p<0.05$).

Impact of macro-aggregate and micro-aggregate on related soil properties

The analysis results of dry macro and micro aggregate stability of two different crop cultivation are presented in (Figure 3). The analysis results showed that dry aggregate stability of two different crop cultivation was significantly different among the crop cultivation while the non-significant with soil layers, mean maximum of macro-aggregate stability was recorded in mustard at 10-20cm 58.31% of the soil layer, while the minimum was recorded in maize 47.71% at 10-20cm of soil layers (Figure 3). On the other side, the mean maximum micro-aggregate stability is 52.29% at 10-20cm soil layer of maize cultivations. The overall trends of both crop cultivation and at both soil layers were recorded as 56.56%, 52.53%, 58.31%, 41.69%, 43.44%, 47.47%, 41.69%, and 52.29%, respectively. Additionally, the analysis results of mean weight diameter (MWD) and GMD (geometric mean diameter) are presented in (Figure 3), results showed that the mean maximum of MWD and GMD 3.87 and 1.99 were recorded in mustard compared to maize 3.68 and 2.04 at 0-10cm of the soil layer, whereas at 10-20cm of soil layers 3.81 and 2.17 of mustard cultivations, 3.23 and 1.81 of maize cultivations respectively, Overall, the MWD and the GMD findings for both crops were substantially distinct ($p<0.05$), although the results within soil layers were non-significant (Figure 3).

Policy Research Journal
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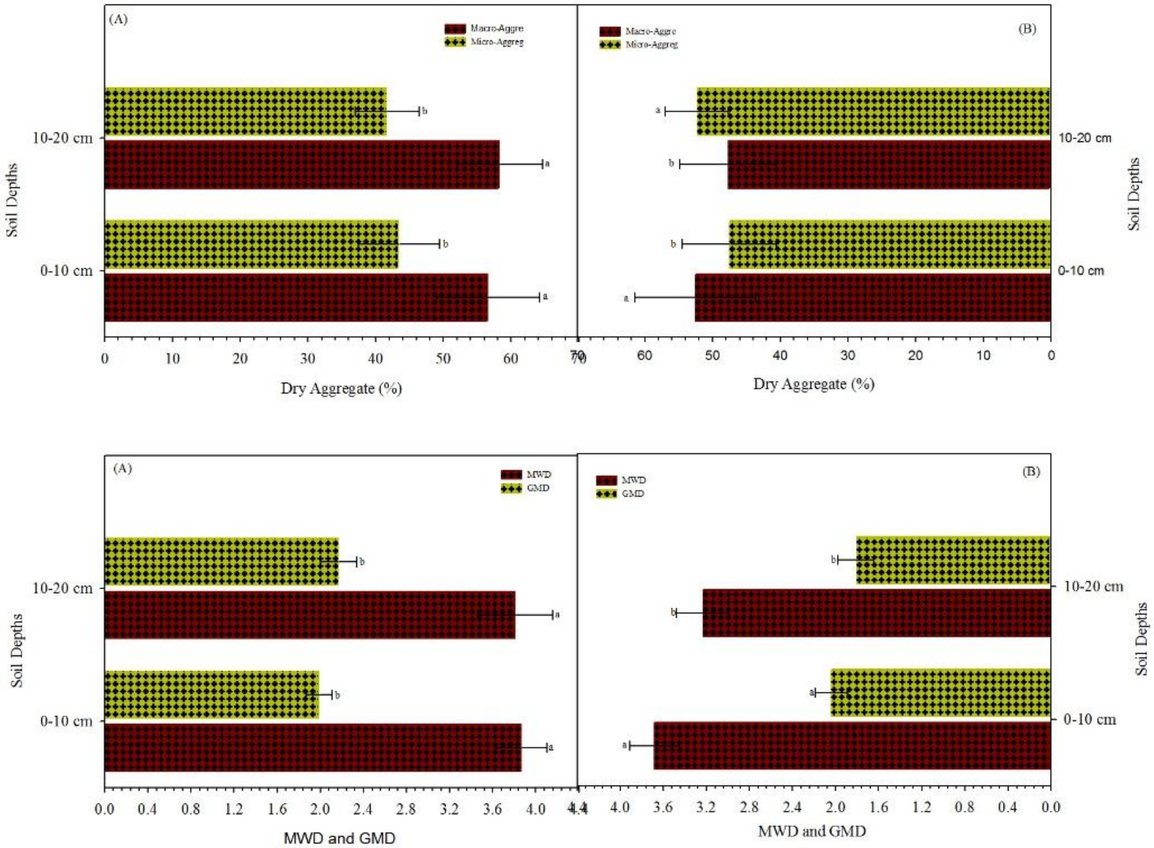

Figure 3: The mean of three replicates with standard errors (±) for two distinct cultivations at 0–15 cm (A) and 15–30 cm soil depth (B) for macro, micro aggregate, MWD (mean weight diameter), and GMD (geometric mean diameter), and the different alphabet (a, b, and c) indicated the significantly different ($p<0.05$).

Correlation matrix among the soil properties and crop cultivations

The correlation matrix of dry aggregate stability and associated soil properties is presented in (Figure 4). Analysis showed that dry sieving of macro-aggregate was significant ($p<0.05$) with nitrogen, phosphorous, and potassium and soil organic matter, non-significant with micro-aggregate, and negatively significant with CDI and DR (%). Furthermore, soil organic matter is significant with nitrogen (mg/kg), phosphorus (%), and potassium (%) and negative with micro-aggregates, CDI, and DR (%). It had been noted that potassium has significant macro-aggregates and phosphorous has highly significant with macro-aggregates, and both were negatively significant with micro-aggregates (Figure 4). MWD and GMD were significant with nitrogen phosphorous and potassium, while potassium was non-significant with GMD (Figure 4). ASC% were non-significant with nitrogen, phosphorous, and potassium while negatively significant with soil EC (dSm^{-1}). The potassium in the soil was positively correlated with nitrogen in the soil. Calcium and Magnesium had a positive correlation among soil EC and pH, while a negative correlation with ASC, CFI, and DR (%) of soil properties (Figure 4).

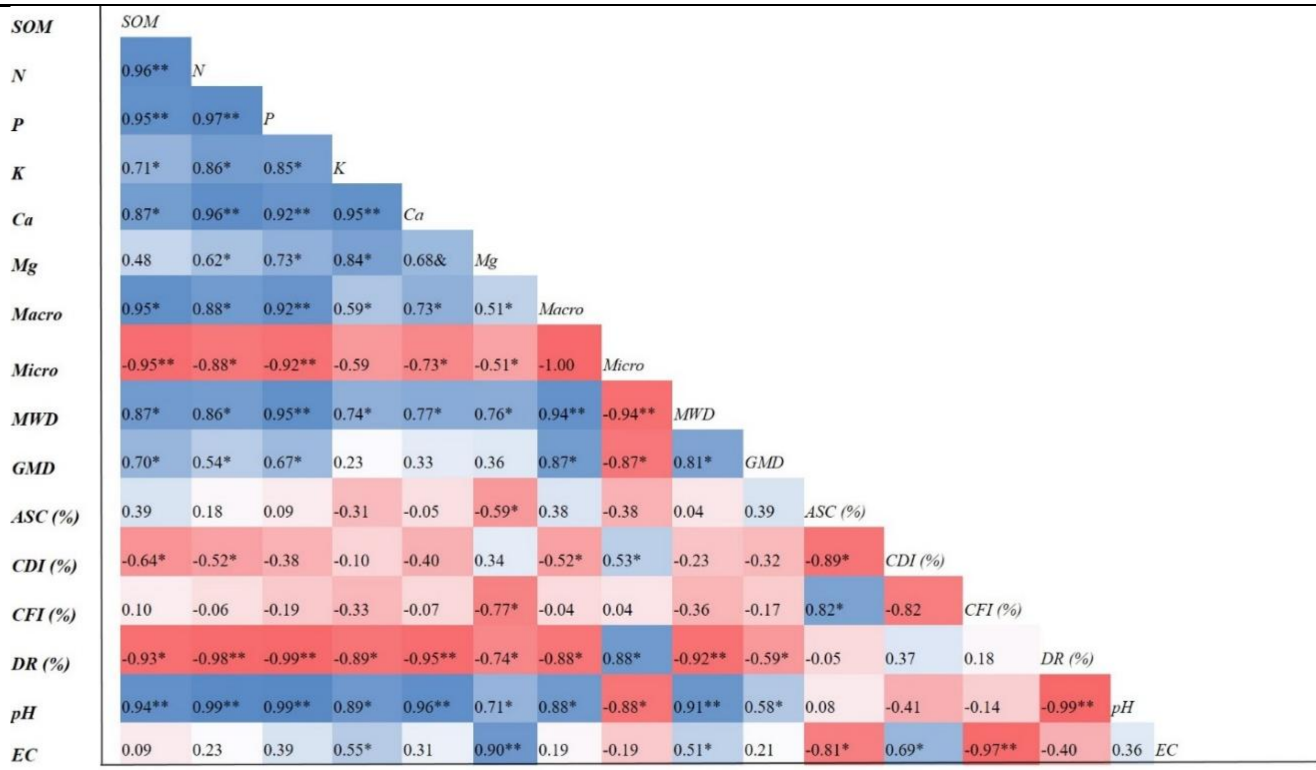

Figure 4: shows the correlation matrix between several soil parameters, including SOM % (soil organic matter), N (nitrogen) mg/kg, P (phosphorous) %, K (potassium) %, Ca (calcium) mg/kg, Mg (magnesium) mg/kg, macro and micro aggregate, MWD (mean weight diameter), GMD (geometric mean diameter), ASC, CFI, DR, CDI (%), pH, and EC dSm^{-1} (electrical conductivity). The different colors indicated the positive and negative significant ($p<0.05$) correlation matrix among the parameters.

DISCUSSION

Soil aggregate stability is a vital indicator of minimizing soil losses and enhancing soil quality; aggregate stability is critical for infiltration, root growth, and resistance to water and wind erosion; unstable aggregates dissolve during rainstorms. Changes in aggregate stability can serve as early indications of soil recovery or degradation, organic matter content, biological activity, and nutrient cycling (Somasundaram et al., 2016). Environmental changes have a common effect on cultivated crops and soil features, and soil microbes, the principal source of soil decomposition, have a considerable impact on soil physicochemical properties and the production of soil aggregates (Liu et al., 2023). In this study, two unique cultivated crops (mustard and maize) were chosen that are frequently produced in Balochistan's dry and semiarid zones, and it was discovered that increasing the SOM% increased aggregate stability (Table 2), which was corroborated by Kalhoro et al., 2019. Similarly, SOM% declines with increasing soil depth, although aggregate stability rises (Table 2, Figure 3), as shown by (Guo et al. 2019; He et al., 2019; Wen et al., 2016). Nitrogen and phosphorus are required by plants in greater quantities than other nutrients at various stages of crop growth, while potassium is also vital for physiological, metabolic, starch translocation, photosynthesis, and enzyme activation. Soil organic matter is an important factor for soil fertility and crop productivity (Rodeni et al., 2024; Yu et al., 2015); the observation of this study also suggests that the increase of available N, available P, and K (Figure 1) could improve the mean weight diameter (MWD), macro-aggregation, and ASC% in mustard compared to maize crop (Figure 3); the findings were endorsed (Liu et al., 2023; Kalhoro et al., 2018); Furthermore, as soil depth increased, so did cultivated crop macro-aggregate formation and ASC%, while SOM% decreased. This might be attributable to dead plant waste, chemical fertilizer use, and microbial activity, which was higher on the surface soil compared to the subsurface layers (Figure 2). Previous research has shown that soil organic matter becomes sensitive to microbial assaults, and mineralization increases. Mean weight diameter is an important soil metric for assessing soil texture, preventing soil erosion, and enhancing the production of dry, stable aggregate (macro- and micro-aggregate). ASC% was observed at mean maximum mean weight diameter values (Figure 3), and the results were previously reported (Yuan et al., 2021; Han et al., 2023). SOM and clay have a direct link with mean weight diameter. Both contribute significantly to the growth of macro-aggregates, micro-aggregates, and ASC%, Kubar et al. (2024) and Kalhoro et al. (2017) validated the results. Soil organic matter is the principal constituent, containing a variety of microbial activity (living and dead organisms), decomposable SOM, and dead plant material. As a result, SOM and soil aggregate stability are two significant features that are closely associated and frequently recognized as key markers of soil quality (productivity), reducing soil erosion as conditions improve (Kumar et al., 2024; Pereira et al., 2023). Furthermore, maize farming had the lowest SOM (figure), which might be linked to farmer practices such as animal grazing, regular plowing, soil degradation, and human activities (Nippert and Knapp, 2007).

Conclusions

Based on the present study observations, our findings showed that macro-aggregate and micro-aggregate have a significant impact on soil properties among both crop cultivations and soil depth (Figure 3). The availability of nitrogen, phosphorous, and potassium has a significant impact on soil aggregate stability. Our investigation found that N, P, K, and OM considerably raised MWD, with OM greatly accelerating the increase in the formation of ASC%, CDI%, CFI%, and DR% (Figure 4) The study found substantial ($p<0.05$) differences in soil physicochemical parameters, including macro-aggregate, ASC%, CDI%, N mgkg-1, P%, K%, and SOM%, between the two cultivation methods (Figure 2). Similarly, a negative correlation was found between micro-aggregate, CDI%, N mgkg-1, P%, and K% Figure 3). Finally, future studies should concentrate on the diverse land-use and crop cultivation strategies that use a combination of organic and inorganic fertilization to decrease soil loss, improve soil fertility, and increase crop yield for sustainable agriculture.

Author Contributions

Shabir Ahmed- Conducted field experiments and compiled the initial draft of the article, Shahmir Ali kalhoro-Planned the research study and overall supervised field and lab experiments, Ammar Rasheed and Punhoon Khan Korai -revised MS, Muammad Abuzar Jaffar and Abdul Hafeez Mastoi-data analysis, Iftakhar Ahmed-organized figures, Muhammad Tahir, **Najeeb ullah,** Suhbat khan and Aidah Baloch-field work, Usama Rasheed, Muneer Ahmed Rodeni and Hakeem Ullah-organized primary data and conducted lab experiments.

Author's Declaration

No conflicts of interest are disclosed by the authors

Acknowledgments

The authors of this research study deeply appreciate the assistance provided by their respective universities and institutes.

REFERENCE

1. Ababaki, B. A., kalhoro, S. A., korai, P. K et al 2024. Estimate the impact of the combined application of n and p fertilizers on the growth of wheat (Triticum Aestivum l.) Under the dry environment of that, balochistan. FUUAST Journal of Biology, 14(1).
2. Ahmed, S., Kalhoro, S. A., Ahmed, B et al 2024. Impact of Humic Acid on the Morphological Components and Growth Parameters of Wheat (Triticum Aestivum L.) Under Dry Climate of Uthal. Journal of Applied Research in Plant Sciences, 5(02), 226-236.
3. Bottinelli, N., Jouquet, P., Capowiez, Y et al 2015. Why is the influence of soil macro-fauna on soil structure only considered by soil ecologists? Soil & Tillage Research, 146:118–124.
4. Franzluebbers, A. J 2010. Achieving soil organic carbon sequestration with conservation agricultural systems in the southeastern

United States. Soil Science Society of America Journal, 74(2):347–357.

5. Gomez, K. A and Gomez, A. A 1984. Statistical procedures for agricultural research. John wiley & sons.
6. Guo, Z.L., Zhang, L.C., Yang, W et al 2019. Aggregate stability under long-term fertilization practices: The case of eroded Ultisols of South-Central China. Sustainability, 11.https://10.3390/su11041169.
7. Han, C., Song, M., Tang, Q et al 2023. Post-farming land restoration schemes exhibit higher soil aggregate stability and organic carbon: Evidence in the Three Gorges Reservoir Area, China. Catena, 227, 107099.
8. He, Y., Gu, F., Xu, C et al 2019. Influence of iron/aluminum oxides and aggregates on plant available water with different amendments in red soils. Journal of Soil and Water Conservation, 74, 145.https://doi.org/10.2489/jswc.74.2.145.
9. Jackson, M. L 2005. Soil chemical analysis: advanced course: a manual of methods useful for instruction and research in soil chemistry, physical chemistry of soils, soil fertility, and soil genesis. UW-Madison Libraries parallel press.
10. Kalhoro, S. A., Ding, K., Zhang, B et al 2019. Soil infiltration rate of forestland and grassland over different vegetation restoration periods at Loess Plateau in northern hilly areas of China. Landscape and Ecological Engineering, 15, 91-99.
11. Kalhoro, S. A., Xu, X., Chen, W et al 2017. Effects of different land-use systems on soil aggregates: a case study of the Loess Plateau (Northern China). Sustainability, 9(8), 1349.
12. Kalhoro, S. A., Xu, X., Ding, K et al 2018. The effects of different land uses on soil hydraulic properties in the Loess Plateau, Northern China. Land degradation & development, 29(11), 3907-3916.
13. Kubar, K. A., Ali, Q., Kalhoro, S. A et al 2024. Dynamics of organic carbon fractions, soil fertility, and aggregates affected by diverse land-use cultivation systems in semiarid degraded land. Journal of Soil Science and Plant Nutrition, 24(1), 524-536.
14. Kumar, J., Bhardwaj, D. R., Thakur, C. L et al 2024. Soil organic carbon dynamics under different land use systems in dry temperate ecosystem of north-western Himalayas. Catena, 240, 108022.
15. Lal, R 2009. Challenges and opportunities in soil organic matter research. European Journal of Soil Science, 60: 158-169.
16. Liu, X., Liu, J., Huang, J. et al 2023. Response of Soil Aggregate Stability to Phosphorus, Nitrogen, and Organic Fertilizer Addition: A Meta-Analysis. Sustainability, 15(13), 10601.
17. Mengal, K. H., Kalhoro, S. A., Rodeni, M. A et al 2024. Evaluation of Variable Rates of Zinc Sulfate Fertilization on Soil Chemical Characteristics, Fertility Status, and Growth Components of Wheat (Triticum Aestivum L): A Case Study on the Hilly Region of Uthal, Balochistan. (2024). Journal of Agriculture and Veterinary Science, 3(2), 299-307. https://doi.org/10.55627/agrivet.003.02.0774
18. Muhammad, T., Khalid, N., Muhammad, U 2014. Impact of humicacid on the morphology and yield of wheat (Triticum aestivum L.). World Applied Sciences Journal, 30(4), 475-480.
19. National Reconstruction Bureau, Government of Pakistan, 2023
20. Nippert, J. B., Knapp, A. K 2007. Linking water uptake with rooting patterns in grassland species. Oecologia. 153: 261–272.
21. Oades, J. M 1984. Soil organic matter and structural stability: mechanisms and implications for management. Plant Soil 76:319–337
22. Pereira, D. G. C., Portugal, A. F., Giustolin, T. A et al 2023. Litter decomposition and nutrient release in different land use systems in the Brazilian semi-arid region. Catena, 231, 107345.

23. Raynolds, W. D., Drury, C. F., Tan, C. S et al 2009. Use of indicators and pore volume-function characteristics to quantify soil physical quality. Geoderma, 152: 252-263.
24. Ren, Z., Zhu, L., Wang, B et al 2016. Soil hydraulic conductivity as affected by vegetation restoration age on the Loess Plateau, China. J. Arid Land, 8: 546.
25. Rodeni, M. A., Kalhoro, S. A., Lahori, A. H et al 2024. Application of potassium co-amended with boron for improving the potassium, boron, growth and yield components of wheat under the dry climate condition of Lasbela Balochistan. Scientific Review Engineering and Environmental Sciences (SREES), 1-17.
26. Shang, W., Zhao, L., Wu, X et al 2015. Soil organic matter fractions under different vegetation types in permafrost regions along the Qinghai-Tibet Highway, north of Kunlun Mountains, China. Journal of Mountain Science, 12:1010-1024.
27. Six, J., Elliott, E., Paustian K 2000. Soil macro-aggregate turnover and micro-aggregate formation: a mechanism for C sequestration under no-tillage agriculture, Soil Biol. Biochem, 32:2099–2103.
28. Somasundaram, J., Reeves, S., Wang, W et al 2016. Impact of 47 years of no-tillage and stubble retention on soil aggregation and carbon distribution in a vertisol. Land Degrad. Develop. 28, no. 5 (2017): 1589-1602.
29. Turner, J., Lambert, M 2000. Change in organic carbon in forest plantation soils in eastern Australia. For. Ecol. Manage; 133: 231–247.
30. Wen, D., Hel, N., Zhang, J 2016. Dynamics of soil organic carbon and aggregate stability with grazing exclusion in the inner Mongolian grasslands. Journal Pone.0146757.
31. Yu, M., Lulu, Zhang., Xue, X et al 2015. Impact of land-use changes on soil hydraulic properties of caloric regosols on the loess plateau, NW china. J. Plant Nutr. Soil Scie. 178(3), 486-498.
32. Yuan, Y., Gao, S., Dai, X et al 2021. Effect of nitrogen and phosphorus addition on soil aggregation and its associated organic carbon. Chemistry and Ecology, 37(7), 603-615.
33. Zhao, L., Wu, W., Xu, X et al 2014. Soil organic matter dynamics under different land use in grasslands in Inner Mongolia (northern China), Biogeosciences, 11, 5103-5113.