Eurasian Journal of Soil Science 2024, 13(2), 125 - 132

Eurasian Journal of Soil Science

Journal homepage : http://ejss.fesss.org

Unveiling the soil physicochemical dynamics of bare soils in Southeast Kazakhstan: A comprehensive study in the Akdala Massif

Ainur Doszhanova [a,*], Zhumagali Ospanbayev [b], Aizada Sembayeva [b], Akgul Kassipkhan [c], Aiman Nazarova [c], Mukhit Bekbauov [a], Dauren Kazkeyev [a]

[a] Kazakh National Agrarian Research University, Almaty, Kazakhstan

[b] Kazakh Research Institute of Agriculture and Plant Growing, Almalybak, Kazakhstan

[c] S.Seifullin Kazakh Agrotechnical Research University, Astana, Kazakhstan

Article Info

Received : 18.06.2023

Accepted : 16.12.2023

Available online : 21.12.2023

Author(s)

A.Doszhanova *

Z.Ospanbayev

A.Sembayeva

A.Kassipkhan

A.Nazarova

M.Bekbauov

D.Kazkeyev

* Corresponding author

Abstract

This study addresses desertification in Kazakhstan's Akdala region, aiming to propose sustainable solutions by examining the effects of various plants on soil properties and nutrient dynamics. Desertification poses a threat to land productivity in arid areas, and this research aims to determine its impact on soil and identify plants for mitigation. Field experiments over three years in the Akdala region utilized crops such as rice, corn, soybean, sudan grass, and sorghum to assess their influence on key soil parameters. Results revealed diverse effects on soil bulk density, agronomically valuable aggregates, water-stable aggregates, labile and total organic carbon, easily hydrolyzable nitrogen, nitrate, available phosphorus, and exchangeable potassium. While no significant differences in bulk density were observed among crops, variations in surface and subsurface soil layers emphasized the importance of depth-specific considerations. Sorghum stood out as a particularly influential crop, significantly increasing labile and total organic carbon levels, highlighting its potential role in enhancing soil quality. The experiments were conducted on the fields of "Birlik" LLP in the Balkhash district of the Almaty region from 2015 to 2017. The chosen crops, each with distinct characteristics, provided a comprehensive understanding of their impact on soil dynamics. Advanced techniques for soil sampling and analyses ensured accurate measurements of various soil parameters. The study site's sharply continental climate, marked by temperature variations, snowy winters, and hot, dry summers, added complexity to the investigation due to its influence on plant growth and soil interactions. In conclusion, this comprehensive study offers valuable insights into the intricate relationships between different crops and soil parameters for combating desertification. The findings contribute significantly to the development of sustainable soil management practices, providing a foundation for identifying suitable crops for soil improvement in arid regions. By understanding how different plants impact soil properties, this research supports informed decision-making in agricultural practices, promoting the long-term sustainability of farming in regions vulnerable to desertification.

Keywords: Desertification, Soil Management, Arid Regions, Phytomelioration, Sustainable Agriculture.

Introduction

Desertification, a complex phenomenon characterized by the decline or loss of land productivity and the transformation of landscapes into desert-like terrain, poses a significant environmental challenge globally. Arid, semiarid, and subhumid arid regions are particularly vulnerable to desertification, a process exacerbated by adverse climate changes and human activities (Geist and Lambin, 2004). This pervasive issue directly

doi : https://doi.org/10.18393/ejss.1408067

: http://ejss.fesss.org/10.18393/ejss.1408067

Publisher : Federation of Eurasian Soil Science Societies

e-ISSN : 2147-4249

impacts over 1 billion people and covers 40% of the world's total land surface (Reynolds et al., 2007; Verón et al., 2006). Kazakhstan, as the largest landlocked country, experiences this challenge acutely with its predominantly arid climate, manifesting in arid grasslands, deserts, and semideserts.

Historically, Kazakhstan has grappled with desertification, especially since the "Black Storm" in the 1960s, marking it as a country deeply affected by land degradation. The Soviet Union and Kazakhstan governments, recognizing the severity of the issue, invested significant efforts in combating and controlling desertification, achieving commendable success (Assanova, 2015). However, post the 1990s, the dynamics shifted with the country's independence and economic recovery. The reclamation of grasslands and the abandonment of croplands became prevalent, leading to an increased risk of land desertification (Hu et al., 2020).

Desertification is intrinsically linked to ecological vulnerability and sensitivity, with Kazakhstan primarily reflecting this through desertification sensitivity due to its arid to semiarid climate (Jiang et al., 2019; Kussainova et al., 2000). Ecological sensitivity becomes a critical factor in assessing the risk and possibility of ecological degradation, encompassing various forms such as desertification sensitivity, soil loss sensitivity, soil salinization sensitivity, and more. In Kazakhstan's context, where aridity prevails, desertification sensitivity takes center stage. The alleviation of saline lands' productivity, crucial in combatting desertification, hinges on the cultivation of crops resilient to soil salinity. Soil salt accumulation can lead to plant stress, posing a threat to agricultural productivity. The theory of the toxic effect of salts on plants highlights the significance of selecting crops that can resist and mitigate the harmful impacts of soil salts (Kvan et al., 2011; Bektayev et al., 2023).

Addressing this challenge, the study explores the influence of sweet clover on soils undergoing secondary salinization. The research investigates the impact of sweet clover on various soil parameters, including nitrogen forms, humus content, and salt-bearing biomass. The findings contribute to the understanding of phytomelioration, an effective and environmentally friendly approach to developing saline lands. The phytomeliorative effect, harnessing the natural potential of plants, offers a sustainable means to improve soil fertility and combat soil salinization, critical components in the broader efforts against desertification.

In light of the above considerations, this study conducts research on the agrobiological methods for the amelioration of degraded irrigated lands in the Akdala irrigation massif. The aim is to provide valuable insights into sustainable soil management practices, offering a potential solution to mitigate the impact of desertification in Kazakhstan's challenging climatic conditions. The primary objective of this study was to assess the impact of different crops on soil properties and nutrient dynamics in the Akdala massif, Kazakhstan, characterized by a sharply continental climate. The aim was to investigate variations in soil bulk density, agronomically valuable aggregates (AVA), water-stable aggregates (WSA), labile and total organic carbon (LOC and TOC), easily hydrolyzable nitrogen (EHN), nitrate (NO_3), available phosphorus (P_2O_5), and exchangeable potassium (K_2O) across various crops, soil depths, and sampling times. The study spanned three years (2015-2017) and utilized field experiments on the fields of "Birlik" LLP in the Balkhash district of the Almaty region, employing a diverse set of crops including rice, corn, soybean, sudan grass, and sorghum. The investigation aimed to enhance our understanding of the intricate relationships between different crops and soil parameters, contributing valuable insights for sustainable soil management practices in continental climates.

Material and Methods

Study site and climatic conditions

The research was conducted in the Akdala massif, Kazakhstan, characterized by a sharply continental climate. This region experiences substantial temperature variations between day and night, as well as between seasons. Winters are cold and snowy, with temperatures as low as -13 to -15°C in January. Conversely, summers are hot and dry, reaching a monthly average high of 23-25°C in July, with an absolute maximum of 40-45°C.Meteorological data from the Bakanas settlement indicate a positive average annual temperature ranging from +5.1 to 7.5°C. The cumulative temperatures above +5°C and +10°C are in the ranges of 3800-4000°C and 3400-3500°C, respectively, facilitating the cultivation of crops with a long growing season. The frost-free period spans approximately 150-160 days on average, with spring frosts ending around April 25 and fall frosts commencing in early October. Annual precipitation is 250 mm, with the majority (64%) falling in the spring-summer period. Summer precipitation, occasionally intense with 50-60 mm in a day, generally does not significantly impact vegetation. The region experiences hard soil freezing during winter (40-50 cm, up to 1 meter in severe winters), and snow cover, lasting 85-100 days, forms from late November to early December. Winter winds cause snow movement into natural depressions.

Experimental design

Field experiments were conducted on the fields of "Birlik" LLP in the Balkhash district of the Almaty region, Kazakhstan. The study focused on bare soils under various crops (rice, corn, soybean, sudan grass and sorghum) in the Akdala irrigation massif. The field trial lasted for three years, from 2015 to 2017.

Table 1. The plants used in the experiment and their planting and harvesting dates

Crops	Planting date	Harvesting date
Rice	April 26	October 15
Corn	April 25	October 5
Soybean	April 25	October 15
Sudan grass	April 25	August 12
Sorghum	April 25	August 12

The experimental layout covered 1 ha, with 5 different plant type, threefold repetition, and a plot area of 230 m^2. Sowing utilized a Vence Tudo direct seeder from Brazil, with ammophos fertilizer (46%N and 12%P_2O_5) applied at 100 kg/ha. Drip irrigation, with recommended rates for each crop, was employed.

Soil sampling and analyses

Soil samples were collected during June and September of each year, at depths of 0-20 cm and 20-40 cm, over the three-year field experimental period (2015-2017). The core method was employed for bulk density analyses. A core sampler, with a 5 cm height and 5 cm diameter metal cylinder, was pressed into the soil. The cylinder, maintaining its height, was removed to obtain a sample of 98.12 cm3 volume. Moist sample weight was recorded, followed by drying in an oven and subsequent weighing (Blake and Hartge, 1986).

Agronomically valuable aggregates (10-0.25 mm) were determined using the standard dry-sieving method, while water-stable aggregates (WSA) larger than 0.25 mm were determined by wet sieving (Kemper and Rosenau, 1986). Total organic carbon (TOC) and labile organic carbon (LOC), Easily Hydrolyzable Nitrogen (EHN) nitrate (NO_3), available phosphorus (P_2O_5), and exchangeable potassium (K_2O) content were determined through various methods, including titrimetric, Kjeldahl, potentiometric, and extraction methods as described by Tyurin (1965); Rowell (1996), Jones (2001), GOST 26213-2021 and GOST 26205-91. The analyses were conducted in the accredited analytical laboratory of the Kazakh Research Institute of Agriculture and Plant Growing.

Results and Discussion

The investigation into the impact of different crops on soil bulk density involved the collection of soil samples at varying time intervals. Figure 1 presents the bulk density values for different crops from 2015 to 2017, considering two soil depths (0-20 cm and 20-40 cm) and two sampling times (July and September). The results depict fluctuations in soil bulk density influenced by various crops. Bulk density is a crucial indicator affecting soil properties, including infiltration, rooting depth, water capacity, porosity, aeration, nutrient availability, and microbial activity (Abbott and Manning, 2015; Makovníková et al., 2017). Analyzing the data, no significant differences in bulk density emerged among crops sampled at different intervals. However, consistently higher bulk density in the 20-40 cm soil depth across all crops implies typical soil behavior, with subsoil layers experiencing greater compaction due to reduced organic matter, aggregation, and root penetration compared to surface soil. This aligns with findings from similar studies (Stirzaker et al., 1996; Duan et al., 2019), reflecting a general increase in bulk density with soil depth. While crop cultivation did not reveal significant differences in bulk density, the consistent increase at 20-40 cm depth emphasizes the importance of considering soil depth variations in understanding bulk density changes. These results contribute to our comprehension of the intricate relationship between different crops and soil bulk density, highlighting the need for comprehensive soil management practices accounting for depth-specific variations.

The investigation into the impact of different crops on Agronomically Valuable Aggregates (AVA) in soils involved soil samples collected at varying time intervals. Figure 2a illustrates the percentage of AVA for different crops from 2015 to 2017, considering two soil depths (0-20 cm and 20-40 cm) and two sampling times (July and September). The results exhibit variations in AVA values influenced by different crops, sampling times, and soil depths. In 2015, Corn demonstrated the highest AVA values in both soil depths, while in 2016, Sudan Grass exhibited the highest AVA values. In 2017, elevated AVA values were observed for both Corn and Sudan Grass. Interestingly, higher AVA values in 2015 were observed in the surface soil (0-20 cm), while in 2016, the 20-40 cm depth exhibited higher AVA values. Dry aggregate size distribution significantly impacts soil fertility, erosion resistance, and degradation, serving as an indicator of soil structure. The structural coefficient, commonly employed in Eastern European countries, highlights the proportion of agronomically valuable fractions (10-0.25 mm) in relation to other fractions (>10 and <0.25 mm) (Shein et al., 2001; Ćirić et al., 2006). The content of these fractions is crucial for optimal porosity, water, and air capacity in the soil. The results emphasize the dynamic nature of AVA values influenced by different crops, sampling times, and soil depths. Shifts between surface and subsurface soils underscore the importance of considering soil depth variations. The relevance of dry aggregate size distribution, indicated by the structural coefficient, emphasizes the significance of agronomically valuable fractions for soil quality and optimal soil properties (Medvedev and Cybulko, 1995; Shein et al., 2001). These findings contribute to our understanding of the intricate relationship between crop cultivation and soil aggregate dynamics, urging further exploration for comprehensive soil management practices.

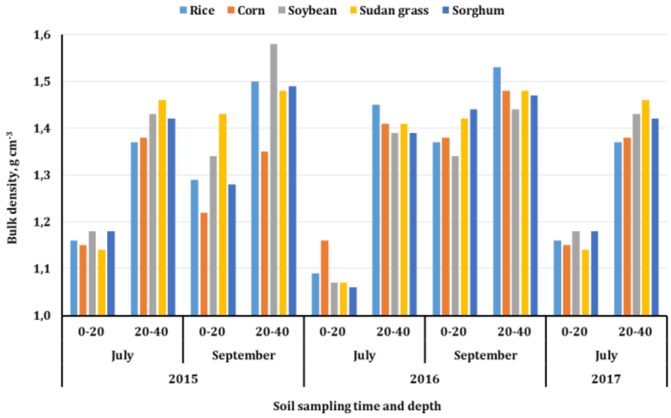
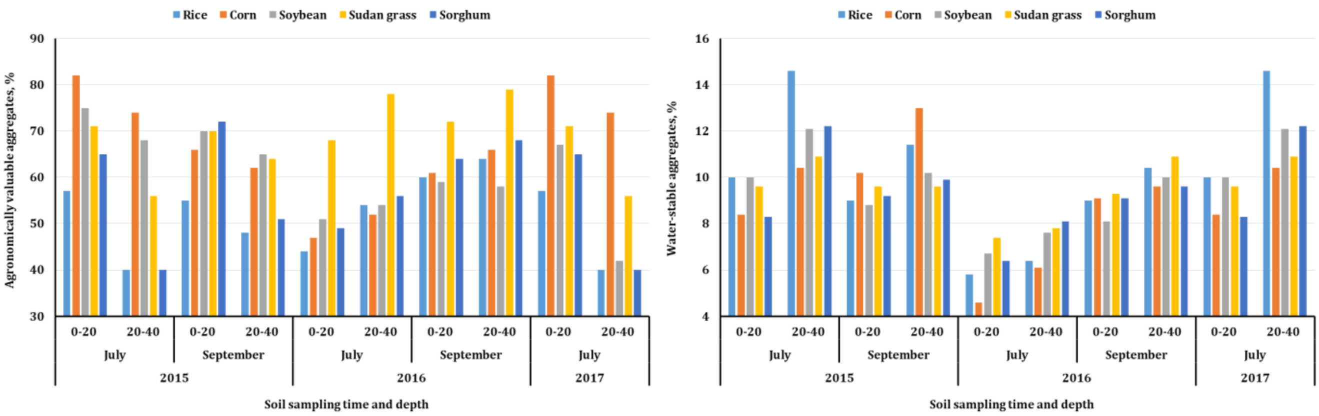


Figure 1. Bulk density variations across different crops, soil depths, and sampling times

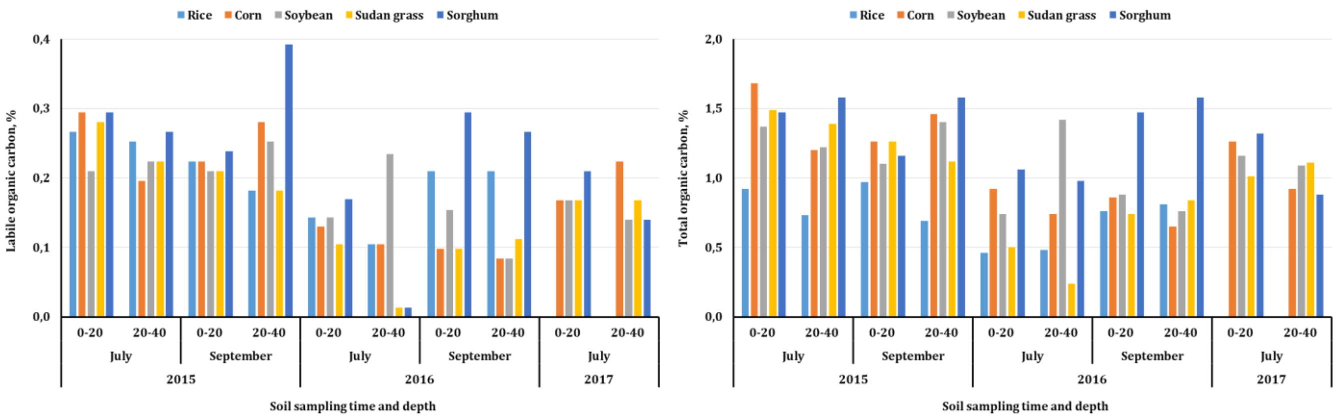
The examination of different crops' influence on Water-Stable Aggregates (WSA) in soils involved collecting soil samples at varying time intervals. Figure 2b depicts the percentage of WSA for different crops from 2015 to 2017, considering two soil depths (0-20 cm and 20-40 cm) and two sampling times (July and September). The results illustrate variations in WSA values influenced by different crops, sampling times, and soil depths. Soil samples from the 20-40 cm depth consistently exhibited higher WSA values during all sampling periods. Significant differences were observed among sampling times and cultivated crops. In July 2015 and 2017, as well as September 2016, Rice recorded the highest WSA values in both soil depths. In September 2016, Sudan Grass demonstrated the highest WSA values. Soil aggregate stability, particularly water-stable aggregates, plays a crucial role in soil health by preserving organic matter, enhancing soil porosity, drainage, and water availability for plants, mitigating soil compaction, and supporting biological activity and nutrient cycling (Papadopoulos, 2011). WSA, especially those >1 mm in size, are indicative of soil structural stability (Tisdall and Oades, 1982). The decline in soil structure is considered a form of soil degradation associated with land use and soil/crop management practices. All sizes of water-stable aggregates contribute significantly to soil quality and serve as indicators of soil health (Sui et al., 2012). The consistently higher WSA values at the 20-40 cm depth highlight the importance of considering soil depth variations in assessing the effects of crop cultivation on soil aggregate stability. These findings contribute to our understanding of the intricate relationship between crop management and soil aggregate dynamics, emphasizing the importance of sustainable soil management practices for maintaining soil health.



(a) (b)

Figure 2. Agronomically Valuable Aggregates (AVA) percentages (a) and Water-Stable Aggregates (WSA) percentages (b) across different crops, soil depths, and sampling times

The investigation into the influence of different crops on Labile Organic Carbon (LOC) and Total Organic Carbon (TOC) in soils involved soil samples collected at varying time intervals. Figure 3a and 3b present the percentage of LOC and TOC, respectively, for different crops from 2015 to 2017, considering two soil depths (0-20 cm and 20-40 cm) and two sampling times (July and September). The results depict variations in LOC and TOC values influenced by different crops, sampling times, and soil depths. Regardless of the sampling time, Sorghum consistently had the highest impact on increasing both Labile Organic Carbon and Total Organic Carbon values in both surface soil (0-20 cm) and subsurface soil (20-40 cm). Notably, these increases were more pronounced in Labile Organic Carbon content. Soil Organic Carbon (SOC) comprises various organic carbon compounds derived from the gradual decomposition of plant residues, animals, and microbial materials (Tian et al., 2015). Labile organic carbon fractions act as transitional fractions between fresh plant residues and stabilized organic matter, with a temporary turnover time (Parton et al., 1987; Wang et al., 2017). These fractions, compared with total SOC, respond to multiple interactions within the soil system and serve as sensitive indicators reflecting shifts in soil quality (Dumale et al., 2009). The results highlight the significant influence of different crops on Labile Organic Carbon and Total Organic Carbon contents in both surface and subsurface soils. Sorghum, in particular, demonstrated a substantial impact on increasing organic carbon levels, emphasizing its potential role in enhancing soil quality. These findings contribute to our understanding of the intricate relationship between crop choices and soil organic carbon dynamics, emphasizing the importance of sustainable agricultural practices for maintaining soil health.

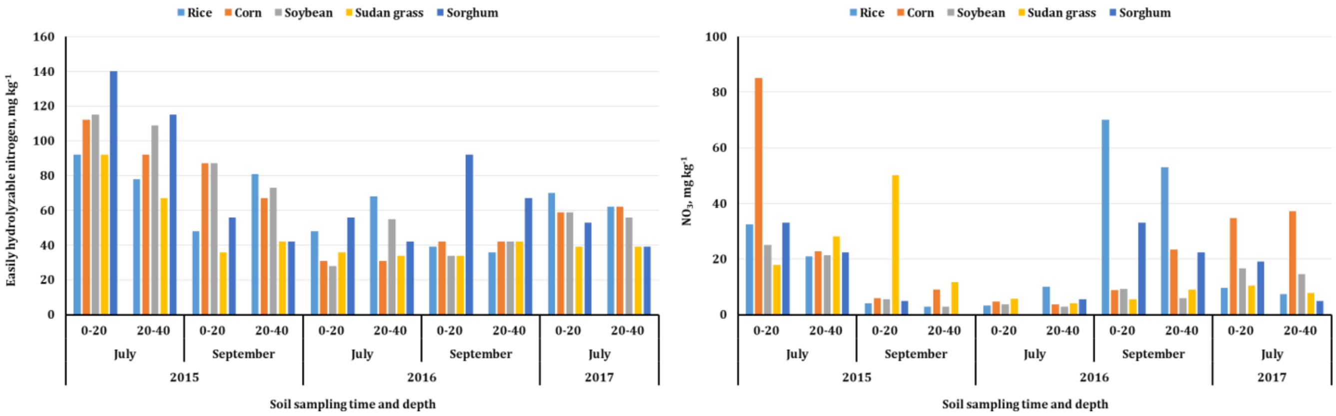


(a) (b)

Figure 3. Labile Organic Carbon (LOC) (a) and Total Organic Carbon (TOC) (b) across different crops, soil depths, and sampling times

The examination of different crops' influence on Easily Hydrolyzable Nitrogen (EHN) and Nitrate (NO_3) in soils involved collecting soil samples at varying time intervals. Figure 4a and 4b present the concentrations of EHN and NO_3, respectively, for different crops from 2015 to 2017, considering two soil depths (0-20 cm and 20-40 cm) and two sampling times (July and September). The results illustrate variations in EHN and NO_3 values influenced by different crops, sampling times, and soil depths. No consistent trend of influence by different crops on EHN and NO_3 content in soil samples collected during all sampling periods was observed. However, in July 2015 and September 2016, the highest EHN values were observed for the Sorghum crop, while in September 2016, the highest NO_3 values were recorded for the Rice crop. Soil available nitrogen is a crucial indicator for evaluating soil nutrients and is directly absorbed by crop roots. Easily hydrolyzable nitrogen represents an alternative indicator of soil nitrogen-supplying capacity, as it is not readily leached and can be directly absorbed by crop roots (Kersebaum et al., 2005; Malhi et al., 2003; Roberts et al., 2011). On the other hand, nitrate (NO_3) is a form of nitrogen directly usable by plants and subject to leaching in soils (Meisinger, 1984). The study provides insights into the dynamic nature of soil nitrogen forms influenced by different crops. The observed variations in EHN and NO_3 content emphasize the importance of considering crop-specific effects on soil nitrogen dynamics. These findings contribute to a better understanding of nutrient cycling in agricultural systems, guiding sustainable practices for maintaining soil fertility and optimizing crop productivity.

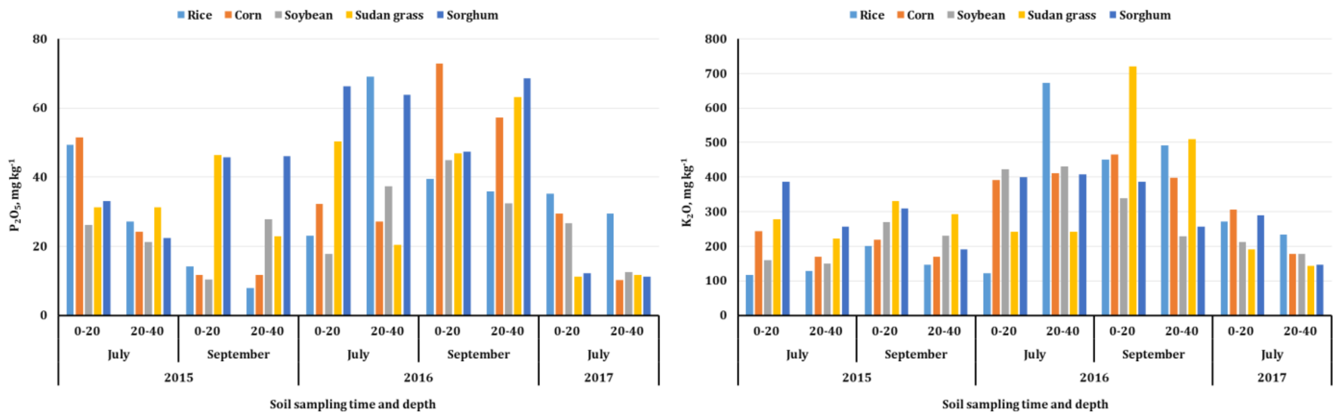
The study aimed to investigate the impact of different crops on available P2O5 and Exchangeable K_2O content in soils, collecting samples at varying time intervals. Figure 5 presents the concentrations of P_2O5 and K_2O for different crops from 2015 to 2017, considering two soil depths (0-20 cm and 20-40 cm) and two sampling times (July and September). The results illustrate variations in available P2O5 and Exchangeable K_2O values influenced by different crops, sampling times, and soil depths.



(a) (b)

Figure 4. Easily Hydrolyzable Nitrogen (EHN) concentrations (a) and Nitrate (NO_3) concentrations (b) across different crops, soil depths, and sampling times

The findings suggest a lack of homogeneity in the influence of plant species on the content of available P_2O_5 and Exchangeable K_2O in soils collected during all sampling periods. This observation may be attributed to the relatively low mobility of phosphorus and potassium compared to nitrogen in the soil. Phosphorus tends to adsorb on calcareous surfaces (Anjos and Rowell, 1987; Eslamian et al., 2021; Zhaksybayeva et al., 2022), while potassium is adsorbed by clay minerals (Binner et al., 2017), resulting in reduced mobility. The study further revealed that the mobility of these two nutrients did not show significant variations between samples taken from the upper soil surface (0-20 cm) and those from the lower soil depth (20-40 cm). However, it is noteworthy that the highest available P_2O_5 content was recorded in the 0-20 cm depth of plots cultivating Corn in September 2016, while the highest Exchangeable K_2O was observed in the 0-20 cm depth of plots cultivating Sudan Grass in September 2016. The results highlight the complex dynamics of available P_2O_5 and Exchangeable K_2O in soils under different crops. The non-uniform effects across plant species emphasize the need for a nuanced approach to soil fertility management, considering the specific nutrient requirements of different crops. These findings contribute to the understanding of nutrient cycling in agricultural ecosystems, aiding in the development of sustainable soil management practices for optimized crop productivity.



(a) (b)

Figure 5. Available P_2O_5 and Exchangeable K_2O concentrations across different crops, soil depths, and sampling times

Conclusion

In conclusion, this study provides valuable insights into the intricate relationship between different crops and soil properties in the Akdala massif, Kazakhstan, characterized by a sharply continental climate. Desertification, a pressing global environmental challenge, particularly affects arid and semiarid regions, impacting over 1 billion people worldwide. Kazakhstan, as the largest landlocked country, faces significant challenges related to desertification, aggravated by adverse climate changes and human activities. Historically, Kazakhstan experienced desertification, marked by the "Black Storm" in the 1960s. Efforts by the Soviet Union and the Kazakhstan government successfully controlled desertification, but post-1990s dynamics, including grassland reclamation and cropland abandonment, increased the risk of land desertification. This study, rooted in the context of combating desertification, aimed to assess the impact of different crops on soil properties and nutrient dynamics in the Akdala massif. The research focused on the cultivation of rice, corn, soybean, sudan grass, and sorghum, employing a diverse set of crops to understand their influence on various soil parameters. The study spanned three years (2015-2017), conducting field experiments on the fields of "Birlik" LLP in the Balkhash district of the Almaty region. The investigation aimed to enhance our understanding of soil bulk density, agronomically valuable aggregates (AVA), water-stable aggregates (WSA), labile and total organic carbon (LOC and TOC), easily hydrolyzable nitrogen (EHN), nitrate (NO_3), available phosphorus (P_2O_5), and exchangeable potassium (K_2O) across different crops, soil depths, and sampling times. The results revealed dynamic variations in soil parameters influenced by different crops, emphasizing the need for comprehensive soil management practices. While soil bulk density did not show significant differences among crops, the consistent increase at the 20-40 cm depth underscored the importance of considering soil depth variations. Agronomically valuable aggregates and water-stable aggregates exhibited fluctuations, showcasing the dynamic nature of soil structure influenced by different crops, sampling times, and depths. The influence of crops on Labile Organic Carbon and Total Organic Carbon demonstrated the significant impact of Sorghum on increasing organic carbon levels, contributing to enhanced soil quality.

The examination of different crops' influence on Easily Hydrolyzable Nitrogen and Nitrate emphasized the dynamic nature of soil nitrogen forms influenced by different crops, sampling times, and soil depths. The findings provide insights into nutrient cycling in agricultural systems, guiding sustainable practices for maintaining soil fertility and optimizing crop productivity. The study further investigated the impact of different crops on available P_2O_5 and Exchangeable K_2O, highlighting the non-uniform effects across plant species and the need for a nuanced approach to soil fertility management. In essence, this research contributes valuable knowledge for developing sustainable soil management practices in arid and semiarid regions. The findings underscore the importance of considering the specific impacts of different crops on soil properties and nutrient dynamics, offering guidance for optimizing soil health and combating desertification challenges. As global efforts intensify to address environmental degradation, studies like this play a crucial role in advancing our understanding and promoting practices that contribute to the sustainable management of ecosystems affected by desertification.

Acknowlegements

The research endeavors were conducted within the framework of the project titled "Agrobiological Methods for the Restoration of Fertility in Degraded Irrigated Lands of Southeast Kazakhstan" identified by the project reference number IRN AP13068063. Furthermore, an application for a utility model patent in the Republic of Kazakhstan, with registration number 2023/1127.2 has been submitted as an integral aspect of this work.

References

Abbott, L.K., Manning, D.A.C., 2015. Soil health and related ecosystem services in organic agriculture. *Sustainable Agriculture Research* 4(3): 116-125.

Anjos, J.T., Rowell, D.L., 1987. The effect of lime on phosphorus adsorption and barley growth in three acid soils. *Plant and Soil* 103: 75–82.

Assanova, M.A., 2015. Public policy and model of sustainable development in the republic of Kazakhstan. *Asian Social Science* 11(6): 237–243.

Bektayev, N., Mansurova, K., Kaldybayev, S., Pachikin, K., Erzhanova, K., Absatova, B., 2023. Comprehensive assessment and information database on saline and waterlogged soils in Kazakhstan: Insights from Remote Sensing Technology. *Eurasian Journal of Soil Science* 12(4): 290 - 299.

Binner, I., Dultz, S., Schellhorn, M., Schenk, M.K., 2017. Potassium adsorption and release properties of clays in peat-based horticultural substrates for increasing the cultivation safety of plants. *Applied Clay Science* 145: 28-36.

Blake, G.R., Hartge, K.H. 1986. Bulk Density. In: Methods of Soil Analysis: Part 1 Physical and Mineralogical Methods, 5.1, Second Edition. Klute, A. (Ed.). American Society of Agronomy, Soil Science Society of America, WI, Madison, USA. pp.363-375.

Ćirić, V., Manojlović, M., Nešić, L., Belić, M., 2012. Soil dry aggregate size distribution: effects of soil type and land use. *Journal of Soil Science and Plant Nutrition* 12 (4): 689-703.

Duan, A., Lei, J., Hu, X., Zhang, J., Du, H., Zhang, X., Guo, W., Sun, J., 2019. Effects of planting density on soil bulk density, ph and nutrients of unthinned Chinese Fir mature stands in south subtropical Region of China. *Forests* 10(4): 351.

Dumale, J.W.A., Miyazaki, T., Nishimura, T., Seki, K., 2009. CO2 evolution and short-term carbon turnover in stable soil organic carbon from soils applied with fresh organic matter. *Geophysical Research Letters* 36(1): 1-6.

Eslamian, F., Qi, Z., Qian, C., 2021. Lime amendments to enhance soil phosphorus adsorption capacity and to reduce phosphate desorption. *Water, Air, & Soil Pollution* 232: 66.

Geist, H.J., Lambin, E.F., 2004. Dynamic causal patterns of desertification. *Bioscience* 54(9): 817–829.

GOST 26205-91. Soils. Determination of mobile compounds of phosphorus and potassium by Machigin method modified by CINAO. Available at [Access date: 11.11.2021]: https://gostperevod.com/gost-26205-91.html

GOST 26213-2021. Soils. Methods for determination of organic matter. Available at [Access date: 11.11.2021]: https://gostperevod.com/gost-26213-2021.html

Hu, Y., Han, Y., Zhang, Y., 2020. Land desertification and its influencing factors in Kazakhstan. *Journal of Arid Environments* 180: 104203.

Jiang, L., Bao, A., Jiapaer, G., Guo, H., Zheng, G., Gafforov, K., Kurban, A., De Maeyer, P., 2019. Monitoring land sensitivity to desertification in Central Asia: convergence or divergence? *Science of The Total Environment* 658: 669–683.

Jones, J.B., 2001. Laboratory guide for conducting soil tests and plant analyses. CRC Press, New York, USA. 363p.

Kemper, W.D. Rosenau, R.C., 1986. Aggregate Stability and Size Distribution. In: Methods of Soil Analysis: Part 1 Physical and Mineralogical Methods, 5.1, Second Edition. Klute, A. (Ed.). American Society of Agronomy, Soil Science Society of America, WI, Madison, USA. pp.425-442.

Kersebaum, K., Lorenz, K., Reuter, H., Schwarz, J., Wegehenkel, M., Wendroth, O., 2005. Operational use of agro-meteorological data and GIS to derive site specific nitrogen fertilizer recommendations based on the simulation of soil and crop growth processes. *Physics and Chemistry of the Earth, Parts A/B/C* 30(1-3): 59-67.

Kussainova, M., Spaeth, K., Zhaparkulova, E., 2020. Efficiency of using the rangeland hydrology and erosion model for assessing the degradation of pastures and forage lands in Aydarly, Kazakhstan. *Eurasian Journal of Soil Science* 9(2): 186 - 193.

Kvan, R.A., Kalashnikov, A.A., Paramonov, A.I., Kaldarova, S.M., 2011. Water resources and prospects for their use in irrigation of the Republic of Kazakhstan. *Vodnoe hozyajstvo Kazahstana* 3: 15-17. [in Russian]

Makovníková, J., Širáň M., Houšková B., Pálka B., Jones, A., 2017. Comparison of different models for predicting soil bulk density. Case study - Slovakian agricultural soils. *International Agrophysics* 31(4): 491–498.

Malhi, S., Gill, K., Harapiak, J., Nyborg, M., Gregorich, E., Monreal, C., 2003. Light fraction organic N, ammonium, nitrate and total N in a thin black Chernozemic soil under bromegrass after 27 annual applications of different N rates. *Nutrient Cycling in Agroecosystems* 65: 201-210.

Medvedev, V.V., Cybulko, W.G., 1995. Soil criteria for assessing the maximum permissible ground pressure of agricultural vehicles on Chernozem soils. *Soil and Tillage Research* 36(3-4): 153–164.

Meisinger, J., 1984. Evaluating plant-available nitrogen in soil–crop systems. In: Nitrogen in Crop Production. Hauck, R.D. (Ed.). American Sciety of Agronomy, Madison, WI, USA. pp. 391-416

Papadopoulos, A., 2011. Soil Aggregates, Structure, and Stability. In: Encyclopedia of Agrophysics. Gliński, J., Horabik, J., Lipiec, J. (Eds.). Encyclopedia of Earth Sciences Series. Springer, Dordrecht. pp 736–740.

Parton, W.J., Schimel, D.S., Cole, C.V., Ojima, D.S. 1987. Analysis of factors controlling soil organic matter levels in Great Plains grasslands. *Soil Science Society of America Journal* 51(5): 1173–1179.

Reynolds, J.F., Smith, D.M.S., Lambin, E.F., TurnerII, B.L., Mortimore, M., Batterbury, S.P.J., Downing, T.E., Dowlatabadi, H., Fernández, R.J., Herrick, J.E., Huber-Sannwald, E., Jiang, H., Leemans, R., Lynam, T., Maestre, F.T., Ayarza, M., Walker,B., 2007. Global desertification: building a science for dryland development. *Science* 316 (5826), 847–851.

Roberts, T., Ross, W., Norman, R., Slaton, N., Wilson, C., 2011. Predicting nitrogen fertilizer needs for rice in Arkansas using alkaline-hydrolyzable-nitrogen. *Soil Science Society of America Journal* 75 (3): 1161-1171.

Rowell, D.L., 1996. Soil Science: methods and applications. Longman, UK. 350p.

Shein, Y.V., Arhangel'skaya, T.A., Goncharov, V.M., Guber, A.K.,Pochatkova, T.N., Sidorova, M.A., Smagin, A.V., Umarova, A.B. 2001. Field and laboratory methods of physical properties and soil status investigations. The University of Moscow, Russia, 199 p. [in Russian].

Stirzaker, R.J., Passioura, J.B., Wilms, Y., 1996. Soil structure and plant growth: Impact of bulk density and biopores. *Plant and Soil* 185: 151-162.

Sui, Y.Y., Jiao, X.G., Liu, X.B., Zhang, X.Y., Ding, G.W., 2012. Water-stable aggregates and their organic carbon distribution after five years of chemical fertilizer and manure treatments on eroded farmland of Chinese Mollisols. *Canadian Journal of Soil Science* 92(3): 551–557.

Tian, H., Lu, C., Yang, J., Banger, K., Huntzinger, D.N., Schwalm, C.R., Michalak, A.M., Cook, R., Ciais, P., Hayes, D., Huang, M.Y., Lto, A., Jain, A.K., Lei, H., Mao, J.F., Pan, S.F., Post, W.M., Peng, S.S., Poulter, B., Ren, W., Ricciuto, D., Schaefer, K., Shi, X.Y., Tao, B., Wang, W., Wei, Y.X., Yang, Q.C., Zhang, B.W., Zheng, N., 2015. Global patterns and controls of soil organic carbon dynamics as simulated by multiple terrestrial biosphere models: current status and future directions. *Global Biogeochemical Cycles* 29(6): 775-792.

Tisdall, J.M., Oades, J.M., 1982. Organic matter and water-stable aggregate in soil *European Journal of Soil Science* 33(2): 141 -163.

Tyurin, I. V., 1965. Organic matter of soil and its role in fertility. Nauka, Moscow. 320p

Verón, S.R., Paruelo, J.M., Oesterheld, M., 2006. Assessing desertification. *Journal of Arid Environments* 66(4): 751–763.

Wang, X.Y., Yu, D.S., Xu, Z.C., Pan, Y., Pan, J.J., Shi, X.Z. 2017. Regional patterns and controls of soil organic carbon pools of croplands in China. *Plant and Soil* 421, 525–539.

Zhaksybayeva, G., Balgabayev, A., Vassilina, T., Shibikeyeva, A., Malimbayeva, A., 2022. Yield of sugar beet and changes in phosphorus fractions in relation to long term P fertilization in chestnut soil of Kazakhstan. *Eurasian Journal of Soil Science* 11(1): 25-32.