University of Sistan and Baluchestan

Journal of Natural Environment Hazards

Print ISSN: 2676 - 4377 Online ISSN: 2676 - 4385

Homepage: https://jneh.usb.ac.ir

Iranian Association of Geomorphology

Journal of Natural Environmental Hazards, Vol.14, Issue 43, March 2025

Investigating the spatial distribution of soil wind-erodible indices using geostatistical methods in the Sistan plain

Ali Shahriari[1*], Seyed Morteza Mohammadi[2], Ebrahim Shirmohammadi[3], Akram Fatemi Ghomesheh[4], Hadi Galavi[5]

1. *Corresponding Author,* Associate Professor, Soil Science and Engineering Department, Faculty of Water and Soil, University of Zabol, Zabol, Iran
2. Assistant Professor, Department of Statistics, Faculty of Basic Sciences, University of Zabol
3. Assistant Professor, Soil Science and Engineering Department, Faculty of Water and Soil, University of Zabol, Zabol, Iran
4. Associate Professor, Department of Soil Science and Engineering, Faculty of Agriculture, Razi University, Iran
5. Assistant Professor, Department of Water Engineering, Faculty of Water and Soil, University of Zabol, Iran

Article Info

Article type:
Research Article

Article history:

Received: 21 July 2024

Revised: 26 August 2024

Accepted: 10 October 2024

Keywords:
Deltaic Soils, Cokriging, Alluvial Activities, Aeolian Activities.

ABSTRACT

The study of land erodibility and its spatial modeling is the main and key information for sustainable land management. Wind erosion is one of the main environmental hazards in Sistan region. Therefore, this research aimed to investigate the spatial changes and modeling of wind erodibility indices in the Sistan Plain. For this purpose, 181 points were selected over the plain, and surface soil was sampled. The studied indices included the laboratory wind-erodible fraction (EF), the wind-erodible fraction based on Fryrear formula (EFF), López formula (EFL), Bouajila formula (EFB), soil crust factor (SCF), dry aggregate stability (DAS) and the soil erodibility. Also, some physical and chemical characteristics were measured in soil samples using standard methods. IDW, kriging, and cokriging were used as geostatistical analysis methods. The results showed that the best variogram model for EFF, SCF, EFB, and DAS was the spherical model, and for EFL, EF, and soil erodibility was the exponential model and the spatial fit for all indices was in the average spatial fit class. The best predictive methods were simple cokriging with covariate of sand for EFF (RMSE=5.724) and soil erodibility (RMSE=85.576), with covariate of clay for EFB (RMSE=2.950) and DAS (RMSE=14.481) and with covariate of sand to clay ratio for EF (RMSE=17.966) and ordinary cokriging method for SCF (RMSE=0.163) and EFL (RMSE=36.312) with covariate of sand to clay ratio. The average values of EFF equal to 29.13%, SCF equal to 0.45%, EFL equal to 75.25%, EFB equal to 83.09%, EF equal to 54.97%, DAS equal to 72.18% and soil erosion equal to 121.67 Mg ha^{-1} yr^{-1}. The highest values of wind-erodible indices were observed in the southern parts of the Sistan plain, and, the lowest values were observed in the northern and western parts. However, the highest value of DAS was found in the northern and western parts and the lowest in the southern part of the plain. There was a high match between the spatial distribution of erodibility indices and the spatial distribution of soil particle size. The changes in soil mineral particles in the region depend on the geomorphic nature of the region and are in line with the changes in the sedimentation regime of the Hirmand River and its branches, as well as wind erosion and sedimentation processes in the Sistan Plain.

Cite this article: Shahriari, A., Mohammadi, S. M., Shirmohammadi, E., Fatemi Ghomesheh, A., & Galavi, H. (2025). Investigating the spatial distribution of soil wind-erodible indices using geostatistical methods in the Sistan plain. Journal of Natural Environmental Hazards, 14(43), 23-28. DOI: 10.22111/jneh.2024.49372.2060

Publisher: University of Sistan and Baluchestan
DOI: 10.22111/jneh.2024.49372.2060

* Corresponding Author Email: shahriari.ali@uoz.ac.ir

INTRODUCTION

One of the most important environmental hazards of arid and desert areas in the world is wind erosion and dust storms as a result. Therefore, the study of land erodibility and its spatial modelling is the main and key information for sustainable land management. One of the new methods of spatial modelling of soil properties is digital soil mapping (DSM), which uses complex models. One of the DSM methods that has been used by researchers for decades is geostatistics. Due to the hyper-arid climate and constant and strong winds known as 120-day winds, wind erosion and dust storms are some of the main environmental hazards in the Sistan region. Therefore, this research was carried out to investigate the spatial changes and modelling of wind erosion indices in the Sistan Plain using geostatistical methods.

DATA AND METHODS

To spatially model the indices of wind erosion, 181 study points in the Sistan plain were selected and their surface soil was sampled. The studied indices included the laboratory wind-erodible fraction (EF), the wind-erodible fraction based on Fryrear formula (EFF), López formula (EFL), Bouajila formula (EFB), soil crust factor (SCF), dry aggregate stability (DAS) and the soil erodibility. Also, 13 physical and chemical characteristics (characteristics related to soil fertility, salinity and sodicity), including percentage of clay, silt, sand (also the ratio of sand to clay), saturated moisture percentage (SP), Electrical conductivity (EC) in saturated extract, soil reaction (pH), percentage of organic matter (OM), soil calcium carbonate equivalent (CCE), cation exchange capacity (CEC), sodium absorption ratio (SAR), available phosphorus (P) and potassium (K) content in soil samples were measured using standard methods. Inverse Distance weighting, Kriging and Cokriging methods were used as geostatistical analysis methods. For each geostatistical method, two simple and ordinary modes were considered, and all the measured soil properties were analyzed as auxiliary variables separately in the Cokriging method. To evaluate the accuracy of the models and choose the best model, the coefficient of explanation (R^2), mean error (ME) and root mean square error (RMSE) were calculated.

RESULTS AND DISCUSSION

The results showed that the soils of Sistan Plain had a medium to coarse texture with the predominance of sand and silt particles, and they had low fertility and were part of saline and sodic soils. The results showed that the best variogram model for EFF, SCF, EFB and DAS was the spherical model and for EFL, EF and soil erodibility was the exponential model, and the spatial fit for all indices was in the average spatial fit class. The best predictive methods were simple Cokriging with covariate of sand for EFF (RMSE=5.724) and soil erodibility (RMSE=85.576), with covariate of clay for EFB (RMSE=2.950) and DAS (RMSE=14.481) and with covariate of sand to clay ratio for EF (RMSE=17.966) and ordinary cokriging method for SCF (RMSE=0.163) and EFL (RMSE=36.312) with covariate of sand to clay ratio. The average values of EFF equal to 29.13%, SCF equal to 0.45%, EFL equal to 75.25%, EFB equal to 83.09%, EF equal to 54.97%, DAS equal to 72.18% and soil erosion equal to 121.67 Mg ha^{-1} yr^{-1}. The highest values of wind-erodible indices were observed in the southern parts of the Sistan plain, and, the lowest values were observed in the northern and western parts. However, the highest value of DAS was found in the northern and western parts and the lowest in the southern part of the plain.

CONCLUSION

In arid areas with significant wind activity, soil wind erodibility indices are very important environmental parameters that can be used for decision-making and land management. The correlation results between the studied wind erodibility indices showed a high correlation of these indices with each other, which shows that the selection of these indices is due to the high correlation regarding the wind erodibility of the soil. The high correlation between EF, DAS and the estimated amount of soil erosion shows the importance of laboratory indicators in estimating erodibility and matching them with the natural environment. The results showed that the use of environmental variables with the cokriging method to prepare a map of soil wind erodibility indices and their spatial modelling is effective. There was a high match between the spatial distribution of erodibility indices and the spatial distribution of soil particle size (sand, silt and clay). The changes in soil mineral particles in the region depend on the geomorphic nature of the region and are in line with the changes in the sedimentation regime of the Hirmand River and its branches, as well as wind erosion and sedimentation processes in the Sistan Plain. The results of this study can be important and practical for managers, decision-makers and land users in the direction of development and sustainable living.

REFERENCES

References (in Persian)

Ali-Soufi, M., Shahriari, A. (2020). Investigation of some chemical properties and amounts of some nutrient elements associated with dust in Sistan Plain. Journal of Natural Environmental Hazards, 9(23), pp 99-116. [in Persian]

Arbab 1, Pahlavanravi 2, Piri Sahragard H, Amiri M. (2018). Accuracy Assessment of Geo-Statistics and Artificial Neural Networks Methods to Estimate Threshold Wind Velocity: A Case of Jazinak Region, Sistan Plain. E.E.R.; 8 (3), pp 87-105. [in Persian]

Asadzadeh, F., Khosravi Aghdam, K., Zawareh, M., Yaghmaian Mahabadi, N., Ramzanpour, H. (2017). Spatial changes of soil mineral particles using geostatistics and remote sensing for soil texture zoning. Water and Soil Journal (Agricultural Sciences and Industries), 32: 7, pp 1222-1207. [in Persian]

Behnam, V., Gholamalizadeh Ahangar, A., Rahmanian, M., Bameri, A. 2019. Spatial Distribution of Some Physical and Chemical Properties of Soil using Geostatistic Methods (Case study: Zabol to Zahedan Route). Environment and Water Engineering, 5:3, pp 251-263[in Persian]

Danesh shahraki, M, Shahriari, A, Ganjali, M, Bameri, A, (2017). Seasonal and Spatial Variability of Airborne Dust Loading Rate over the Sistan Plain Cities and its Relationship with some Climatic Parameters. J. of Water and Soil Conservation, 6 (23), pp 199-216. [In Persian]

Dahmardeh, A., Shahriari, A., Pahlavan Rad, M. R., Shabani, A., Ghorbani, M. (2021). Modeling wheat yield using some soil properties at the field scale (Case study: Sistan dam research farm, university of Zabol). Agricultural Engineering, 44(1), pp 81-95. [In Persian]

Delarami, A., Gholamalizadeh, A., Shabani, A. (2020). Determining Optimal Combination of Input Variables Using Gamma Test for Absorbable Potassium Modeling in the Fuzzy-Neural System (Case Study: Mian-Kangi Region Zabol). Crop Science Research in Arid Regions, 2(1), pp 67-75. [In Persian]

Gholamallizade Ahangar, A., Sarani, F., Hashemi, M., Shabani, A. 2015. Comparison of Linear Regression Methods, Geostatistical and Artificial Neural Network Modeling of Organic Carbonin Dry Land of Sistan Plain, Journal of Water and Soil. 6:28, pp 1250-1260. [in Persian]

Hashemi, M, Gholamalizadeh Ahangar, A, Bameri, A, Sarani, F, Hejazizadeh, A, (2016), Survey and Zoning of Soil Physical and Chemical Properties Using Geostatistical Methods in GIS (Case Study: Miankangi Region in Sistan), Journal of Water and Soil, 30 (2), pp 443-458. [In Persian]

Jafarnia, S., Akbarinia, M. 2014. Investigation of spatial distribution of soil and water properties by use of geostatistical in Mangrove forest of Qeshm Island. Iranian Journal of Forest and Poplar Research. 22:4, pp 673-686. [in Persian]

Jamalzehi Samareh, Y., Shahriari, A., Pahlavan Rad, M., Ziaei Javaid, A., Bameri, A. (a, 2021). Preparation of three-dimensional maps of the size of soil particles in the floodplain of Sistan. The seventeenth Iran Soil Science Congress and 4th National Farm Water Management Conference, Soil and Water Research Institute, Karaj. [in Persian]

Jamalzehi Samareh, Y., Shahriari, A., Pahlavan Rad, M., Ziaei Javaid, A., Bameri, A. (b, 2021). Application of geostatistics in preparing three-dimensional maps of saturation percentage of soil (Case study: Sistan plain). The seventeenth Iran Soil Science Congress and 4th National Farm Water Management Conference, Soil and Water Research Institute, Karaj. [in Persian]

Matinfar, H., Maqsoodi, Z., Mousavi, S., Jalali, M. (2019). Evaluation of machine learning methods in digital organic carbon mapping of agricultural soils (part of Khorram Abad plain). Water and Soil magazine. 24:4, pp 343-327. [in Persian]

Mir, H., Gholamallizadeh Ahangar, A., Shabani, A., (2016), Determination of the Most Important Soil Parameters Affecting the Availability of Phosphorus in Sistan Plain, Using Connection Weight Method in Neural Networks, Journal of Water and Soil, 9(26), pp 1674-1687. [In Persian]

Nazari Samani, A. A., Ehsani, A. H., Golivari, A., Abdolshahnejad, M. (2015). Comparing the Results of RWEQ and IRIFR Models for Determining Land Management Effects on Wind Erosion. Desert Management, 3(6), pp 39-53. [in Persian]

Noori, A., Eftekhari, K., Efandiari, M., Mohammadi Torkashvand, A., Ahmadi, A. (2022). Estimation of soil erodible fraction using artificial neural network models and integration of artificial neural network with genetic algorithm in the part of Qazvin province. E.E.R. 12 (1), pp 145-159. [in Persian]

Ostwari Y., Qurbani Dashtaki, S., Bahrami, H., Naderi, M., Abbasi, M. (2014). Spatial changes of soil erodibility and factors affecting it upstream of Sivand dam. Quantitative Geomorphology Research, 4 (3), pp 127-144. [In Persian]

Owliaie, H., Salehi, A., Zareian, G. 2024. Assessment of geostatistical models for zoning spatial distribution of some soil properties in Darengan region with different land uses, Fars province. Iranian Journal of Soil and Water Research. 55:1, pp 97-116. [In Persian]

Refahi, H. (2014). Water erosion and its control (7th edition). Tehran University Press, 674 p.

Rezazadeh, S., Gholamalizadeh, A., Ghazmeh, S., Froughifar, H., Bameri, A. (2016). Evaluation of Different Interpolation Methods in Spatial Estimation of Soil Properties in Sistan Plain. Water and Soil Science, 26(2-2), pp 151-162. [in Persian]

Tajik, F., Rahimi, H., Pazira, A, (2002. The effect of soil organic matter, electrical conductivity and sodium adsorption ratio on the tensile strength of aggregates, Journal of Science and Technology of Agriculture and Natural Resources, 3, pp 1-15. [In Persian]

Vaezi, A., Bahrami, H., Sadeghi, S., Mahdian, M. (2008). Determining the estimating error of USLE erodibility factor in calcareous soils of Northwestern Iran. Water and Soil, 22(2), pp 61-71. [in Persian]

Yaghmaeian Mahabadi, N., Samiei, K., Zavvareh, M., Ramezanpour, H. (2019). Spatial variation of some soil properties and their relationship to tea yield in Fouman region, Guilan. Applied Soil Research. 7:2, pp 82-96. [in Persian]

References (in English)

Abdel-Rahman, M.A., Zakarya, Y.M., Metwaly, M., Koubouris, G. (2021). Deciphering Soil Spatial Variability through Geostatistics and Interpolation Techniques. Sustainability, 13, pp 194.

Akhzari, D., Farokhzadeh, B., Saeedi, C, I., Goodarzi, M, (2015), Effects of Wind Erosion and Soil Salinization on Dust Storm Emission in Western Iran, Journal of Rangeland Science, 5(1), pp 36-48.

Alizadeh Motaghi, F., Hamzehpour, N., Mola ali abasiyan, S., Rahmati, M. (2020). The wind erodibility in the newly emerged surfaces of Urmia Playa Lake and adjacent agricultural lands and its determining factors. Catena, 194, pp 104675.

Borrelli, P., Ballabio, C., Panagos, P. and Montanarella, L. (2014). Wind erosion susceptibility of European soils. Geoderma, 232–234, pp 471-478.

Borrelli, P., Lugato, E., Montanarella, L., Panagos, P. (2017). A New Assessment of Soil Loss Due to Wind Erosion in European Agricultural Soils Using a Quantitative Spatially Distributed Modelling Approach. Land Degradation & Development, 28, pp 335 - 344.

Bouajila, A., Omara, Z., Ajjari, A., Bol, R., Brahim, N., (2022). Improved estimation and prediction of the wind-erodible fraction for Aridisols in arid southeast Tunisia. Catena, 211, pp 106001.

Cambardella, C.A., Moorman, T.B., Novak, J.M., Parkin, T.B., Karlen, D.L., Turco, R.F., Konopka, A.E. (1994). Field-scale variability of soil properties in central Iowa soils. Soil Science Society of American Journal, 58, pp 1501-1511.

Colazo, J.C., Buschiazzo, D.E. (2010). Soil dry aggregate stability and wind erodible fraction in a semiarid environment of Argentina. Geoderma, 159, pp 228-236.

Delbari, M., Afrasiab, P., Gharabaghi, B., Amiri, M., Salehian, A. (2019). Spatial variability analysis and mapping of soil physical and chemical attributes in a salt-affected soil. Arabian Journal of Geosciences, 12:3, pp 68-86. doi:10.1007/s12517-018-4207-x.

Fryrear, D.W., Saleh, A., Bilbro, J.D., Schomberg, H.M., Stout, J.E., Zobeck, T.M. (1998). Revised Wind Erosion Equation (RWEQ), Wind Erosion and Water Conservation Research Unit, USDA-ARS- SPA Cropping Systems Research Laboratory. Technical Bulletin No 1.

Gholami V., Sahour H., Amri M. A. H. (2021). Soil erosion modeling using erosion pins and artificial neural networks. Catena, 196, pp 104902.

Guo, Z., Chang, C, Wang, R., Li, J. (2017). Comparison of different methods to determine the wind-erodible fraction of soil with rock fragments under different tillage/management. Soil & Tillage Research, 168, pp 42–49.

Han, Y., Zhao, W., Ding, J., Santos Ferreira, C.S. (2023). Soil erodibility for water and wind erosion and its relationship to vegetation and soil properties in China's drylands. Science of the Total Environment, 903, pp 166639.

Jiang, H.L., Liu, G.S., Liu, S.D., Li, E.H., Wang, R., Yang, Y.F., Hu, H.C. (2012). Delineation of site-specific management zones based on soil properties for a hillside field in central China. Archives of Agronomy and Soil Science. 58:10, pp 1075-1090.

Kadović, R., Miljković, P., Perić, V., Živanović, N., Bohajar, Y.M.A., Belanović Simić, S. (2014). An analysis of an erodible fraction of sandy soils in Deliblato Sands. Erozija, Udruženje bujičara Srbije, 40, pp 38–52. (in Serbian with English abstract)

Karaoglu, M., Erdel, E. (2023). Soil properties and mapping of the Aralik-Igdir wind erosion area-I (surface). Carpathian Journal of Earth and Environmental Sciences, 18 (2), pp 277 – 288.

Karimi Nezhad, M. T., Tabatabaii, S. M., Gholami, A. (2015). Geochemical assessment of steel smelter-impacted urban soils, Ahvaz, Iran. J. Geochem. Explor. 152, pp 91-109.

Kouchami-Sardoo I., Shirani H., Esfandiarpour-Boroujeni I., Besalatpour A., Hajabbasi M. (2020). Prediction of soil wind erodibility using a hybrid Genetic algorithm–Artificial neural network method. Catena, 187, pp 104315.

Ling, N., Zhibao, D., Weiqiang, X., Chao, L., Nan, X., Shaopeng, S., Fengjun, X., Lingtong, D. (2018). A field investigation of wind erosion in the farming–pastoral ecotone of northern China using a portable wind tunnel: a case study in Yanchi County. Journal of Arid Land, 10(1), pp 27-38.

López, M.V., de Dios Herrero, J.M., Hevia, G.G., Gracia, R., Buschiazzo, D.E. (2007). Determination of the wind-erodible fraction of soil using different methodologies. Geoderma, 139, pp 407–411.

Mina, M., Rezaei, M., Sameni, A., Ostovari, Y., Ritsema, C.J. (2022). Predicting wind erosion rate using portable wind tunnel combined with machine learning algorithms in calcareous soils, southern Iran. Journal of environmental management, 304, pp 114171.

Mina, M., Rezaei, M., Sameni. A., Riksen, M.J.P.M., Ritsema, C. (2023). Estimation of Soil Erodibility by Wind Using Pedo-Transfer and Spectro-Transfer Functions and Machine Learning Models in Fars Province. Geoderma, 438, pp 116612.

Mirakzehi, K., Pahlavan-Rad, M., Shahriari, A., Bameri, A. (2018). Digital soil mapping of deltaic soils: a case of study from Hirmand (Helmand) river delta. Geoderma, 313, pp 233-240.

Pahlavan-Rad, M. Dahmardeh, K., Brungard, C. (2018). Predicting soil organic carbon concentrations in a low relief landscape, eastern Iran. Geoderma Regional, e00195. https://doi.org/10.1016/j.geodrs.2018.e00195

Pahlavan-Rad, M.R., Akbarimoghaddam, A. (2018). Spatial variability of soil texture fractions and pH in a flood plain (case study from eastern Iran). Catena, 160, pp 275-281.

Pásztor, L., Négyesi, G., Laborczi, A., Kovacs, T. (2016). Integrated spatial assessment of wind erosion risk in Hungary. Nat. Hazards Earth Syst. Sci. 16, pp 2421–2432. https:// doi.org/10.5194/nhess-16-2421-2016.

Pi, H., Huggins, D.R., Sharratt, B. (2019). Dry aggregate stability of soils influenced by crop rotation, soil amendment, and tillage in the Columbia Plateau. Aeolian Research, 40, pp 65-73.

Rakkar, M.K., Blanco-Canqui, H., Tatarko, J. (2019). Predicting soil wind erosion potential under different corn residue management scenarios in the central Great Plains. Geoderma, 353, pp 25–34.

Rezaei, M., Mohammadifar, A., Gholami, H., Mina, M., Riksen, M.J.P.M., Ritsema, C. (2023). Mapping of the wind erodible fraction of soil by bidirectional gated recurrent unit (BiGRU) and bidirectional recurrent neural network (BiRNN) deep learning models. Catena, 223, pp 106953.

Sarani, F., Ahangar, A.G., Shabani, A. (2016) Predicting ESP and SAR by artificial neural network and regression models using soil pH and EC data (Miankangi Region, Sistan and Baluchestan Province, Iran). Archives of Agronomy and Soil Science, 6 (1), pp 1-12. DOI: 10.1080/03650340.2015.1040398

Schaetzl, R. J., Anderson, S, (2005). Soils: Genesis and Geomorphology, Cambridge University Press, 833 Pp.

Selmy, S.A., Abd El-Aziz, S., El-Desoky, A., El-Sayed, M.A. (2022). Characterizing, predicting, and mapping soil spatial variability in the Gharb El-Mawhoub area of Dakhla Oasis using geostatistics and GIS approaches. Journal of the Saudi Society of Agricultural Sciences, 21, pp 383-396.

Shahriari, M., Delbari, M., Afrasiab, P., Pahlavan-Rad, M.R. (2019). Predicting regional spatial distribution of soil texture in floodplains using remote sensing data: A case of southeastern Iran. Catena, 182, pp 104-149. doi:10.1016/j.catena.2019.104149.

Shiyatyi, E.I., (1965). Wind structure and velocity over a rugged soil surface. Vestnik Sel.-khoz. Nauki 10.

Sirjani, E., Sameni, A., Moosavi, A.A., Mahmoodabadi, M., Laurent, B. (2019). Portable wind tunnel experiments to study soil erosion by wind and its link to soil properties in the Fars province, Iran. Geoderma, 333, pp 69–80. https://doi.org/10.1016/j.geoderma. 2018.07.012.

Skidmore, E.L., Hagen, L.J., Armburst, D.V., Durar, A.A., Fryrear, D.W., Potter, K.N., Wagner, L.E., Zobeck, T.M. (1994). Methods for investigating basic processes and conditions affecting wind erosion. In: Lal, R. (Ed.), Soil Erosion Research Methods. Soil & W. Cons. Soc. Ankeny, USA, pp. 295–330.

Zobeck, T.M., Van Pelt, R.S. (2014). Wind Erosion. Publications from USDA-ARS / UNL Faculty. 1409.