World Academy of Science, Engineering and Technology
International Journal of Geological and Environmental Engineering
Vol:18, No:6, 2024

Physical Deterioration of Semi-Arid Soils as Affected by Land Use Change in North West of Iran

Ali Reza Vaezi, Fereshteh Haghshenas

***Abstract*—**Land use has generally been considered a local environmental issue, but it is becoming a force of global importance. Extensive changes to forests and pastures are being driven by the need to provide food, fiber, and shelter for people in recent decades. Land use is an important factor affecting soil organic carbon accumulation and storage in soils which influence directly on other physicochemical soil properties, soil productivity and soil's susceptibility to water erosion. The change of pastures to the agricultural lands has been increasing rapidly in most semi-arid regions in Iran. Information on the effect of the land use change in these areas on the deterioration of soil physicochemical properties is limited. Therefore, this study was conducted to investigate the physical deterioration of soil as affected by land use change in semi-arid pastures in north west of Iran. Toward this, seven areas covering both pasture and rainfed lands with different soil textures (clay loam, silty clay loam, sandy clay loam, silt loam, loam, sandy loam and sandy loam) were selected in a semi-arid region in Zanjan, NW Iran. Pasture in the area is covered with poor vegetation and mostly grazed in wet seasons (end of winter and early spring and autumn). Rainfed lands resulting land use change are mostly planted for winter wheat production. In each area, soil samples (0-30 cm depth) were collected from the two land uses (pasture and rainfed land) at three replications. A total of 42 soil samples were taken from the study area. Various soil physical properties consisting of bulk density, total porosity, coarse pores volume, aggregate size, aggregate stability, water-holding capacity and saturated hydraulic conductivity were determined in the soil samples using the laboratory conventional methods. The results showed that the change of pastures to rainfeds is severely deteriorated soil physical properties. However, the variation rate of the physical soil properties is different. The loss of soil physical properties as a result of the land use change was in the following order: 61% water-stable aggregates, 60% aggregate size > 41% macroporosity > 28% bulk density > 22% total porosity > 11% water holding capacity > 5% saturated point. This result reveals that the structural characteristics of soils in this area are the most important soil physical characteristics that are affected by land use change. The deterioration of these soil properties influences negatively the pore size distribution and volume percentage of macroporosity. Effects of land use change on deterioration of soil physical properties were different in various soil textures. The highest mean loss of soil physical properties was found in loam (42%), whereas the lowest value was in silty clay loam (23%). As a consequence, loam is the most vulnerable soil to physical degradation caused by land use change in the pastures. This physical loss of soil is associated with its higher percentage of larger aggregates as well as water-stable aggregates.

***Keywords*—**Pasture, soil physical properties, soil structural characteristics, soil texture.

I. Introduction

LAND use is one of the most important factors influencing the key characteristics and ecological functions of soil around the world. Improper land use and mismanagement of land resources lead to soil degradation and is known as a serious challenge for food security and ecosystem sustainability [1]. Changing the use of forests and pastures land to agriculture land has become one of the significant concerns in the world in terms of environmental degradation and global climate change [2]. Many studies show that decreasing the surface of forests and pastures and turning them into agricultural lands has caused destruction or disruption of natural ecosystems [3]-[5]. These human activities have reduced the soil productivity, and increased soil erosion by water, pollution and salinity in the soil [3]. Soil erosion, resulting from land use change, is especially an important environmental problem in arid [3] and semi-arid region [6]. In these areas' soils are poorly covered by vegetation and soils have lower organic matter and aggregate stability which sensitive them to water erosion processes [6]. In most arid and semi-arid regions, soil erosion and its physical and chemical changes are the most serious threats to agriculture, which result in the loss of nutrients, soil instability, and reduced yield of agricultural products [7].

Literature review shows that that land use change and rainfall erosion have significant impacts on soil erosion [8]. Research on the effect of land use change in forests and pastures on soil erosion in semi-arid regions of Brazil showed that soil erosion increased 10 times in the lands [4]. Soil depth is a fundamental property of the soils which is strongly affected by the land use change. It is one of the most critical factors which impact on culture productivity and makes difficult appropriate management decisions [9]. Investigating on the characteristics of sodium soils in different land uses in northwest India indicated that with increasing soil depth, some physicochemical properties including bulk density and hydraulic conductivity of the soil increase [5]. Result of a study in Brazil showed that land use change leads to a decrease in soil percolation and aggregate stability [10]. It reveals soils in the areas with less land use change generate less runoff and are more resistance to water erosion processes.

In most semi-arid regions in Iran, poor pastures are changed to dry-farming lands, an action that increases the sensitivity of soils to water erosion processes. It is important to investigate effects of land use change of pastures to dry-farming lands on

Ali Reza Vaezi is Professor with Department of Soil Science and Engineering, Faculty of Agriculture, University of Zanjan, Iran (corresponding author, e-mail: vaezi.alireza@znu.ac.ir).

Fereshteh Haghshenas is Former Ph.D. Student with Department of Soil Science and Engineering, Faculty of Agriculture, University of Zanjan, Zanjan, Iran.

the physical soil properties in semi-arid regions. Therefore, this study was conducted to determine variation of physical soil properties in some change land uses with various soil textures in a semi-arid region in Iran.

II. Materials and Methods

The sampling area was a part of the soils of the semi-arid region in Zanjan province located in northwest of Iran (Fig. 1). Pastures in the area are poor and are grazed in wet seasons (end of winter and early spring). Some of these lands have change to dry-farming lands for the decades. Rainfed lands are mostly planted by winter wheat with a grain yield of 1 t ha-1 yr-1, on average. The field investigation of the soils of the region showed that the soils have low organic matter content and are weakly-aggregated especially in farms with intensive cultivation and without fallow and rotation [6]. The soils located in slope land are tilled along slope that accelerates soil erosion by water [11].

Land use change and conventional tillage are the main the important factors of soil physical deterioration which increase soil susceptibility to water erosion. There was a need to area with both pasture and change pastures to agriculture to compare soil physical properties. Therefore, the areas that were under rainfed cultivation and there was virgin soil (weak pasture) were considered for soil sampling. Seven sits were considered to study of soil physical properties. In each site, the land with both rainfed and pasture land which just have similar soil texture were selected. Soil samples were taken (0 to 30 cm depth) from each land uses (pasture and rainfed lands) at three replicates in each sit. Firstly, soil samples were air-dried and passed from a sieve 8 mm. In total, 42 six samples (six soil samples from six seven sits) were taken from the study sites and transferred to the laboratory in the University of Zanjan.

Along with particle size distribution and organic matter content, some soil physical properties consisting of porosity, macroporosity percentage, bulk density, water holding capacity, saturated point, aggregate size, water-stable aggregates and saturated hydraulic conductivity were determined in the soil samples. Differences between the two land uses in soil physical properties were tested using t-test.

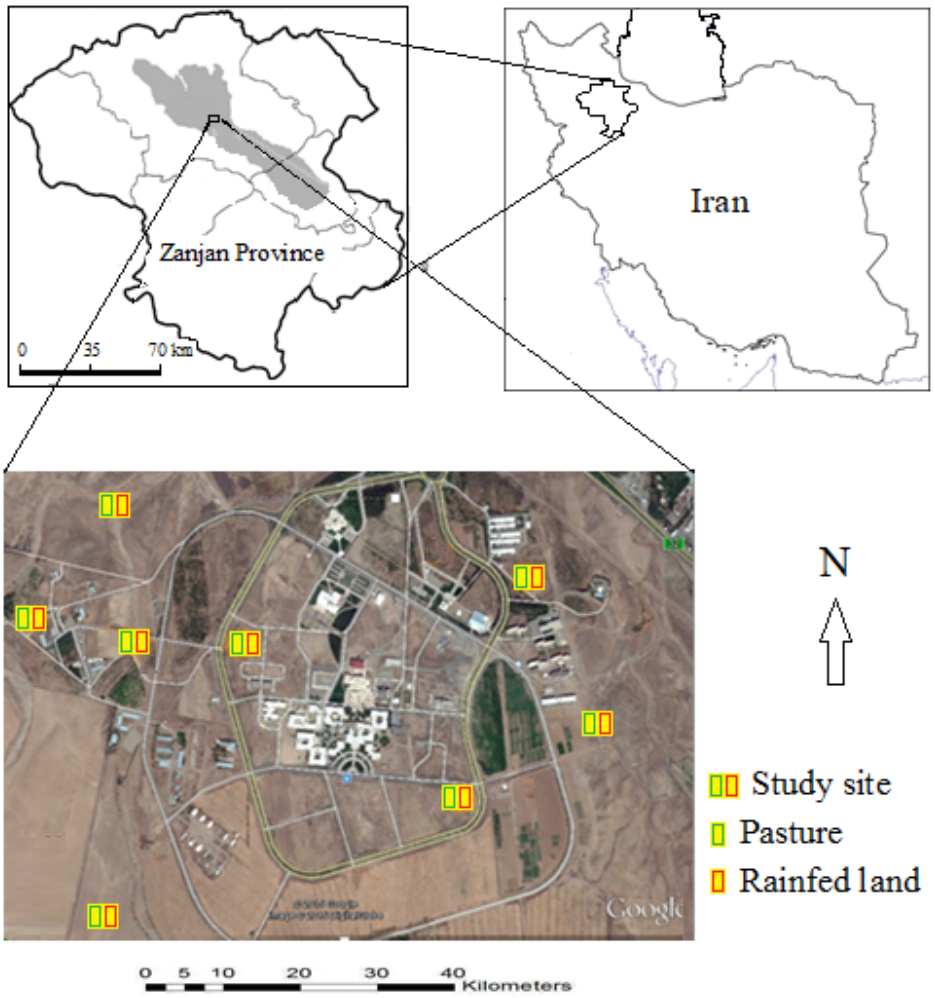

Fig. 1 Location of the study sits and sampling points in Zanjan province, NW of Iran

III. Results and Discussions

The physical and chemical properties of the studied soils are presented in Table I. Soil textures in the sits were: clay loam, silty clay loam, sandy clay loam, silt loam, loam, sandy loam and loamy sand. The soils have lower organic matter content ranging from 0.3% in sandy clay loam to 0.9% in silt loam. Bulk density in the soils was between 1.2 g cm^{-3} in clay to 1.4 g cm^{-3} in sandy loam. Total porosity varied from 43.7% in silty clay loam to 55.8% in clay loam. Similar to this, the highest and lowest value of macroporosity percentage was in silty clay loam (23%) and clay loam (35%), respectively. Sandy loam had the lowest water saturated point (31%), while loam showed the highest value (45.7%). Medium-soil textures (sandy clay loam, silt loam and loam) have higher aggregate stability as well as water-stable aggregates. These soils except loam had the higher hydraulic conductivity, indicating the role of soil structure in easily water drainage from soil.

The results showed that the land use change of pastures to rainfed farms strongly leads to the physical deterioration of soils (Table II). The highest and lowest deterioration of soil bulk density was from 17.2 (silt loam) to 30.7 (silty clay loam). Soil porosity deteriorated from 9.4% in silty clay loam to 29.5% in sandy loam. Macroporosity also showed relatively similar loss in the soils, so that the lowest and highest value was in sandy clay loam (25.9% in silty clay loam) and loam (54.7%), respectively. The loss of water holding capacity varied from 5.6% in silt loam to 17.6% in loam. Saturated hydraulic conductivity appeared less deterioration; so that it was ranged from 2.3% in silty clay loam to 6.4% in silt loam. Nevertheless, the highest variation was found in structural characteristics; aggregate size decreased from 36.5% in sandy loam to 82.6% in loam, and water-stable aggregates declined from 39.7% in loamy sand to 79.3% in sandy clay loam.

TABLE I
Physical and Chemical Properties of Virgin Soils

Soil properties	Soil texture						
	Clay loam	Silty clay loam	Sandy clay loam	Silt loam	Loam	Sandy loam	Loamy sand
Sand (%)	26.9	19. 1	55.0	33.9	45.7	67.2	75.0
Silt (%)	35.6	43.5	22.4	53.6	36.8	25.3	17.5
Clay (%)	37.5	37.4	22.6	12.5	17.5	7.5	7.5
Organic matter (%)	0.4	0.3	0.3	0.9	0.6	0.8	0.7
Bulk density (g/cm^3)	1.2	1.2	1.3	1.3	1.2	1.4	1.3
Porosity (%)	55.8	43.7	47.9	51.7	54.7	47.1	51.3
Macroporosity (%)	35.0	23.0	33.0	30.0	31.0	32.0	34.0
Water holding capacity (%)	20.2	20.3	14.0	20.8	23.3	14.4	17.1
Saturated point (%)	39.4	41.1	31.0	42.3	45.7	36.8	31.5
Aggregate size (mm)	1.1	1.5	2.4	2.5	2.2	0.8	1.7
Water-stable aggregates (mm)	0.5	0.4	1.0	1.1	1.0	0.9	0.8
Hydraulic conductivity (cm/h)	5.3	6.5	8.2	10.2	2.8	13.9	3.2

TABLE II
Changes in Soil Physical Properties Due to Land Use Change

Soil texture	Changes in soil physical properties (%)						
	Bulk density ($g\ cm^{-3}$)	Porosity (%)	Macroporosity (%)	Water holding capacity (%)	Saturated point (%)	Aggregate size (mm)	Water-stable aggregates (mm)
Clay loam	30.2	24.4	42.8	8.6	4.1	75.9	69.6
Silty clay loam	30.7	9.4	25.9	8.1	2.3	39.3	44.3
Sandy clay loam	31.0	24.4	39.3	13.9	6.3	82.1	79.3
Silt loam	17.2	16.1	33.2	5.6	6.4	54.2	55.0
Loam	35.8	28.3	54.7	17.6	2.7	82.6	75.3
Sandy loam	26.4	29.5	46.9	10.5	3.2	36.5	75.1
Loamy sand	27.3	24.9	44.1	11.0	5.9	65.6	39.7
Average	28.4	22.4	41.0	11.0	4.6	62.3	63.0

Results indicated that the bulk density, total porosity, macroporosity, saturated hydraulic conductivity, water holding capacity, saturated point, aggregate size, and water-stable aggregates were degraded with a rate of 28, 22, 41, 11, 5, 60 and 61% by the land use change, on average (Fig. 2). This result shows that the structural characteristics of semi-arid soils (aggregate size and stability in water) are the most susceptible physical properties to the land use change. The deterioration of these soil properties affects the pore size distribution and so decreases macroporosity. According to less role of soil structure on water storage in the soil, there was no large effect of land use change on soil saturated point (SP). Nevertheless, water holding capacity was affected by deterioration of soil structure. These physical soil properties can directly control water supply and crop yield in rainfed lands. Findings on the effects of pasture and forest change to cultivated land in a Mediterranean region in Turkey showed that soil structure and bulk density vary significantly by the land use change. They fund that the cultivation of the pastures degraded the soil physical properties, leaving soils more susceptible to water erosion [12]. Result of severe land-use change in Himalayan regions in India showed that water-stable aggregates were highest in the grassland while

bulk density was the highest in the changed lands. The grassland soils retained the highest amount of water retention, while the soils in the changed lands had significantly lower water retention than the grassland and forest soils [13].

Mean loss of soil physical properties by the land use change varied from 23% in silty clay loam to 42% in loam (Fig. 3). This result indicated that, loam is the most susceptible soil to physical deterioration by the land use change. Indeed, the land use change in the pastures with loamy soils leads to the greatest physical destruction of the soil in the area. This result can be related to higher soil structure development. The soils with larger aggregates and stable water aggregates are more the susceptible to physical deterioration by the land use change in pastures. Effect of the land use change in decreasing aggregate stability and infiltration rate has been reported in Cerrado located in Brazil [7].

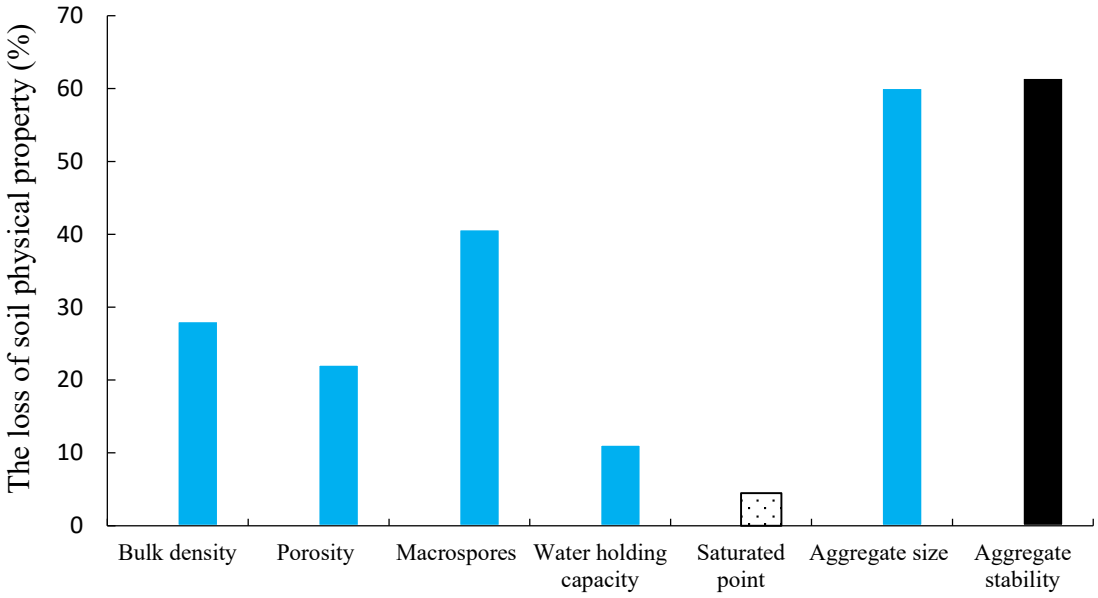

Fig. 2 The loss of soil physical properties by the land use change in Zanjan province, NW of Iran

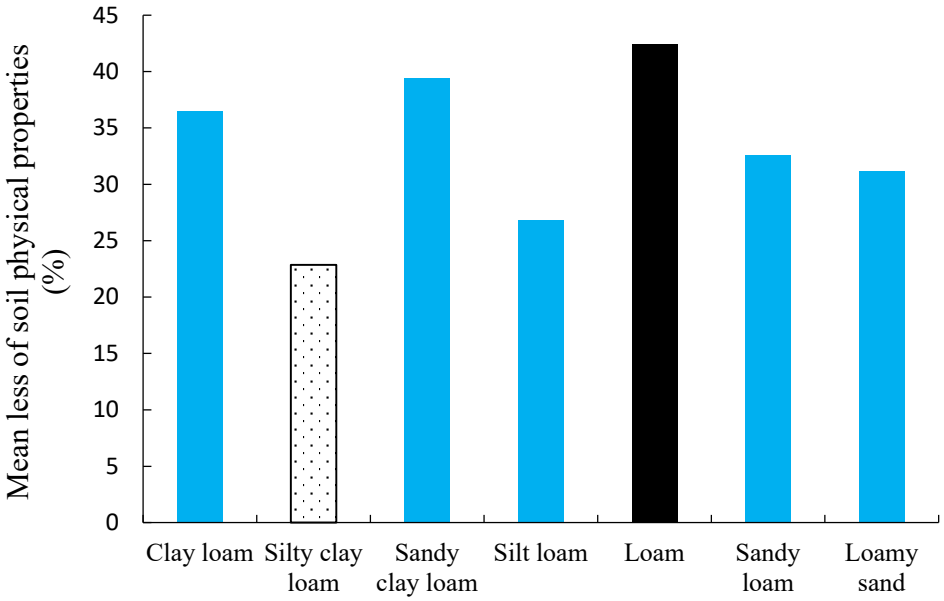

Fig. 3 Mean loss of soil physical properties by the land use change in different soil textures, NW of Iran

IV. Conclusion

Land use type is an important factor controlling soil quality especially in view point of soil physical properties. The change of pastures to the agricultural lands is an important environmental challenge in most semi-arid regions in Iran. In this study, seven areas covering both pasture and rainfed lands with different soil textures (clay loam, silty clay loam, sandy

clay loam, silt loam, loam, sandy loam and sandy loam) were selected in a semi-arid region in north west of Iran. Various soil physical properties were determined in the soil samples taken from the two land uses in each area. The results showed that loam is the most vulnerable soil texture to physical degradation caused by land use change in the pastures. The change of pastures to rainfeds is severely deteriorated; soil physical properties consist of soil aggregation aggregate stability, bulk density, porosity, macropores percentage and water holding capacity. The structural characteristics of soils were the most important soil physical characteristics that were largely affected by land use change. The deterioration of these soil properties influences negatively the pore size distribution and macropores percentage.

REFERENCES

[1] Ebabu, K., Tsunekawa, A., Haregeweyn, N., Adgo, E., Meshesha, D. T., Aklog, D., Yibeltal, M. 2020. Exploring the variability of soil properties as influenced by land use and management practices: A case study in the Upper Blue Nile basin, Ethiopia. Soil and Tillage Research, 200: 104614.

[2] Akinde, B. P., Olakayode, A. O., Oyedele, D. J., Tijani, F. O. 2020. Selected physical and chemical properties of soil under different agricultural land-use types in Ile-Ife, Nigeria. Heliyon, 6(9).

[3] Tadesse, L., Suryabhagavan, K. V., Sridhar, G., Legesse, G. 2017. Land use and land cover changes and soil erosion in Yezat Watershed, North Western Ethiopia. International soil and water conservation research, 5(2): 85-94.

[4] Santos, J. C. N. D., Andrade, E. M. D., Medeiros, P. H. A., Guerreiro, M. J. S., Palácio, H. A. D. Q. 2017. Land use impact on soil erosion at different scales in the Brazilian semi-arid1. Revista Ciência Agronômica, 48: 251-260.

[5] Datta, A., Basak, N., Chaudhari, S. K., Sharma, D. K. 2015. Soil properties and organic carbon distribution under different land uses in reclaimed sodic soils of North-West India. Geoderma Regional, 4: 134-146.

[6] Vaezi, A.R. and Bahrami, H.A., 2014. Relationship between soil productivity and erodibility in rainfed wheat lands in northwestern Iran. Journal of Agricultural Science and Technology, 16(6): 1455-1466.

[7] Obiahu, O. H., Kalu, A. I., Uchechukwu, N. 2020. Effect of tectona grandis biochar on soil quality enhancement and yield of cucumber (Cucumis Sativus L) in highlyweathered nitisol, Southeastern Nigeria. J. Wastes Biomass Manag (JWBM), 2(2): 41-48.

[8] Fu, A., C, Y., Sun, T., Li, F. 2021. Estimating the impact of land cover change on soil erosion using remote sensing and GIS Data by USLE model and scenario design. Scientific Programming, 2021: 1-10.

[9] de Sousa, G.P.B., Tayebi, M., Campos, L.R., Greschuk, L.T., Amorim, M.T.A., Rosas, J.T.F., de Oliveira Mello, F.A., Chen, S., Ayoubi, S. and Demattê, J.A., 2023. Improvement of spatial prediction of soil depth via earth observation. Catena, 223, p.106915.

[10] Hunke, P., Roller, R., Zeilhofer, P., Schröder, B., Mueller, E. N. 2015. Soil changes under different land uses in the Cerrado of Mato Grosso, Brazil. Geoderma Regional, 4: 31-43.

[11] Sadeghian, N., Vaezi, A. R., Majnooniheris, A., Cerdà, A. 2021. Soil physical degradation and rill detachment by raindrop impact in semi-arid region. Catena, 207, 105603.

[12] Celik, I. 2005. Land-use effects on organic matter and physical properties of soil in a southern Mediterranean highland of Turkey. Soil and Tillage research, 83(2): 270-277.

[13] Saha, D., Kukal, S. S. 2015. Land degradation and development, 26(3) 263-271.