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Effect of Long- term Agricultural Practices on Soil Iron Oxides Forms and Mineralogy in the Vertisols of the Piranshahr Region

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Introduction: Human activities such as intensive cultivation and land use changes alter nutrients fluxes (mainly iron) and mineralogy in soil and terrestrial ecosystems. Iron is an essential element for plants and microorganisms and its solubility is controlled by stable hydroxides, oxyhydroxides, and oxides. In general, parent material, climate, and landscape position are the major factors that accelerate the weathering of the minerals and rocks containing Fe in the regional scale. However, long-term cultivation and intensified agriculture may be the dominant attributes of modifications in soil properties like Fe compounds mainly in arid and semiarid regions, where the irrigational and agricultural practice is current over long-term periods. Although substantial data is documented on Vertisols properties, few studies are available to assess the effects of long-term continuous cultivation on the characteristic and distribution of iron oxides and their mineralogy, mainly in calcareous environments.

Materials and Methods: This study was conducted in the Piranshahr - Pasvah area (36° 46 to 36° 50 N and 45° 09 to 45° 50 E, 1500 m above sea level), West Azarbaijan Province, northwest of Iran. Six soil profiles belonging to three subgroups of Vertisols order (Chromic Calcixererts, Typic Haploxererts, and Typic Calcixererts) were described and sampled from the cultivated soils and similar soils from the nearby uncultivated region as grassland. Soil samples were air-dried and passed through a 2-mm mesh sieve before the analysis. Soil analysis included particle-size distribution, pH and electrical conductivity (EC), soil organic carbon (SOC), calcium carbonate equivalent (CCE), cation exchange capacity (CEC), the determination of iron oxides forms and mineralogical composition. Free or pedogenic Fe oxides (Fed) including crystalline, poorly crystalline, and organically bound Fe were extracted by dithionite–citrate–bicarbonate (DCB) method. Poorly crystalline and organically bound Fe (Feo) were extracted using 0.2 M ammonium oxalate (AO). Organic complex of Fe (Fep) was extracted by 0.1 M Na-pyrophosphate at pH 10. All Fe oxide forms were determined using atomic absorption spectrometry. The difference between DCB-Fe and AO-Fe was considered as an estimation of crystalline Fe oxides form.

Results and Discussion: The results showed that long-term cropping caused a considerable drop in organic carbon and calcium carbonates along with a noticeable rise in the values of clay and cation exchange capacity as a result of accelerated alteration by farming activities and interactions between the used irrigation water and soils receiving it. Long-term cultivation improved the amount of Fed and Fecry (crystalline Fe) from 1 to 64% and 44 to 90%, respectively, than those of uncultivated soils which can be explained in some pathways: (1) accelerated weathering of Fe-bearing minerals (such as biotite, chlorite, feldspars, amphibole, and pyroxene) in the cultivated soils and (2) the higher temperature condition and the more number of wetting–drying cycles in the cultivated soils compared to the uncultivated soils. Despite the fact that long-term cultivation caused a significant decrease in organic matter, a pronounced increase in organic complex of Fe with the range of 19 to 61% was recorded with farming practices. Such pattern can be contributed to the chemistry of organic matter and the presence of more stable fraction (passive fraction) of soil organic matter in the cultivated soils. The XRD patterns of primary Fe-bearing minerals (such as amphibole, pyroxene, and feldspar) had less intense in the cultivated soils compared to those of the adjacent uncultivated soils, indicating that probably cultivation promoted the instability and weatherability of Fe-bearing minerals as well as the loss of Fe from the minerals. In contrast, the X-ray reflections of secondary Fe-oxide minerals such goethite appeared to be higher, sharper and intense by long-term cropping, suggesting that agricultural practices also promoted the crystallization of the soil Fe oxides. Compared to the uncultivated soils, long-term agricultural practices caused some changes in X-ray reflections of chlorite, illite, and smectite.

Conclusions: The results showed that the weathering of Fe-bearing minerals and layer silicates, as well as the production of Fe oxide forms were promoted under long-term continuous cropping. Under cultivation, a pronounced increase in Fe-oxide forms, particularly Fed and Fecry, was recorded for the most of the examined

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soils which can be associated with the combined effects of increased soil temperature and moisture content from irrigation and farming practices. As emphasized, the combined effects of increased compounds from agricultural input (such as chemical and organic fertilizers, the compound of irrigation water, and moldboard tillage) as well as increased precipitation from irrigation interacted to create conditions for: (1) more intense the weathering of Fe-bearing minerals and (2) the more production of iron oxides forms in the cultivated soils.

Keywords: Crystalline iron, Cultivated soil, Mineralogy, Pedogenic iron