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Spatio-temporal variability in physical properties of different textured soils under similar management and semi-arid climatic conditions

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ABSTRACT

Soil physical properties play an important role in determining soil's suitability for agricultural uses. The purpose of our study was to characterize spatio-temporal variations in moisture content (θ_m), bulk density (ρ_b), aggregate stability (AS) and penetration resistance (PR) of different textured soils under similar management and climatic conditions. A 25 × 25 m area was monitored in each of the 3 fields with Daphan clay (Haplustert), Ciftlik loam (Fluvaquent), and Ciftlik sandy loam (Ustorthent) from September 2014 to August 2015. Each area was divided into 5 × 5 m cells. Undisturbed soils from 0 to 10 cm depth at 36 intersection points were collected monthly, and processed and analyzed. Results showed that spatio-temporal changes in soil properties were strongly affected by natural freezing-thawing and wetting-drying processes. While the θ_m increased with rainfall and/or snow melts through September–January, the θ_m decreased onwards February. The θ_m ranged between 11.50 and 56.34% for the Daphan clay, 7.26 and 41.92% for the Ciftlik loam, and 2.52 and 33.83% for the Ciftlik sandy loam, with highest variabilities in January and November, and the lowest variabilities in July and August. The decrease in θ_m was closely and linearly associated ($r = -0.94^{**}$) with ρ_b and vice versa. However, the temporal variation in AS was primarily due to θ_m and its effects on freezing-thawing and swelling/shrinking during wetting-drying cycles. While the lowest AS was measured in February, the highest AS was observed in July for the Daphan clay, and August for the Ciftlik loam and Ciftlik sandy loam, respectively. The AS linearly and inversely related to θ_m ($r = -0.66^{**}$). Likewise, the PR decreased linearly with an increase in θ_m, and vice versa. While the θ_m linearly decreased the PR ($r = -0.45^{**}$), the ρ_b increased PR ($r = 0.45^{**}$). Results suggested that spatio-temporal variations in core soil physical properties could provide useful information for site-specific precision agricultural management practices to improve soil quality.

1. Introduction

Sustainable agriculture is important to support economic crop production with enhanced agroecosystem services. While crop productivity is greatly influenced by the integrated functional effects of soil properties, soil dynamic physical properties influence both the chemical and biological properties in determining soil's suitability for agricultural uses. The supporting capability of soil as a medium for plant growth; the movement, retention and availability of water and nutrients to plants; field workability and ease in penetration of plant roots; and heat and air flow and circulation are all impacted by soil physical properties (Pardo et al., 2000; Franzluebbers, 2002; Bronick and Lal, 2005).

Soil is a complex and dynamic system with functional properties that are highly variable over time and space (Some'e et al., 2011). Generally, the sources of soil property variability are associated with the result of intrinsic (natural) or extrinsic (cultural and/or management related) processes. Geological, hydrological, and biological factors that affect pedogenesis are main factors of intrinsic soil variability (Webster, 2000; Zhao et al., 2007). In contrast, the extrinsic variability from cultural and/or management influences can be the results of variable tillage operations, irrigation and drainage, field traffic operations, soil amendments, and harvesting and residue management (Angulo-Jaramillo et al., 1997; Iqbal et al., 2005; Mubarak et al., 2009).

While spatial variability in soil properties is strongly scale dependent and may change within the micro-scale and regional scales (Webster, 1985), soil temporal variability may occur during the cropping season and from year to year depending on weather or climatic conditions (Strudley et al., 2008; Mubarak et al., 2010). Soil physical

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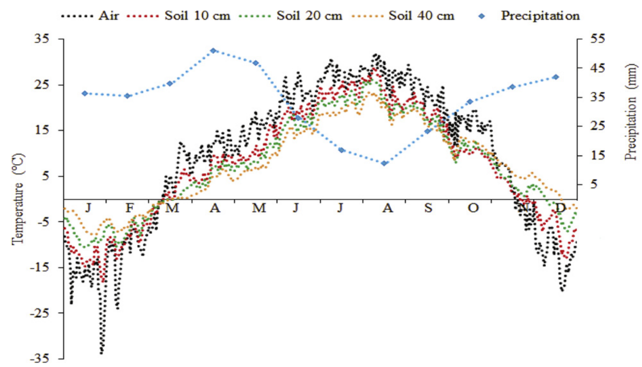

Fig. 1. Soil (10, 20 and 40 cm depth) and air temperatures and precipitation during the experimental period.

properties, such as moisture content (θ_m), bulk density (ρ_b), aggregate stability (AS), and penetration resistance (PR) are inter-dependent properties, and are strongly influenced by seasonal changes in climate and climate-induced pedological factors especially soil wetting-drying and freezing-thawing processes (Blackman, 1992; Bodner et al., 2013; Moreira et al., 2016).

Soil structure is one of the core indicators of soil quality that affects other processes important to soil productivity, environmental and water quality, and agricultural resiliency (Bronick and Lal, 2005). Soil structure influences not only the content and air, heat and water exchange processes, it also affects mechanical support and the fate of reactive agrochemicals (Lal, 1991). Furthermore, improved soil structure can reduce the risks of erosion, compaction and flooding, and improve infiltration, drainage and biodiversity, the degraded soil structures severely affect these properties and processes (Connolly, 1998; Six et al., 2004).

While classical statistical analyses assume that the measured data to be independent, several other studies, in contrast, have shown a strong spatial dependence of soil properties (Journel and Huijbregts, 1991; Shi et al., 2007). Geostatistics, which enables the interpretation of results based on the structure of natural variability, can be used to define and explain the spatial dependency of soil properties, both isotropically and anisotropically (Goovaerts, 1997; Júnior et al., 2006; Some'e et al., 2011).

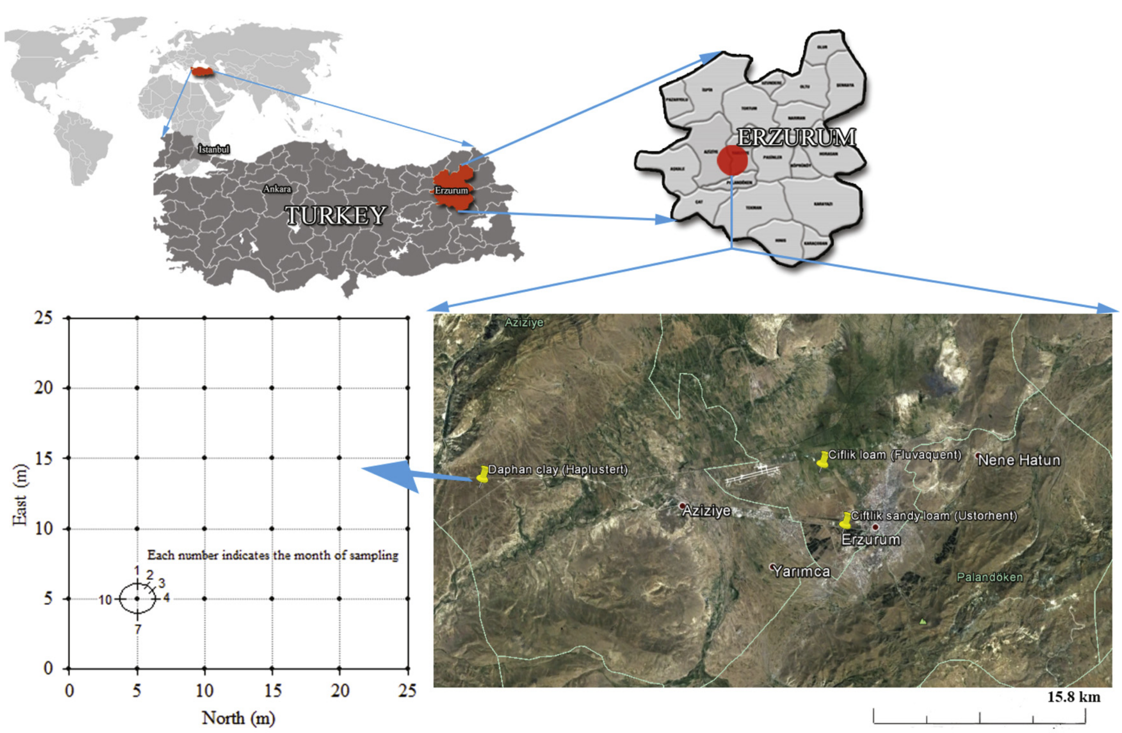

Fig. 2. Layout of soil sampling locations.