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Modeling Runoff from Semi-Arid Agricultural Lands in Northwest Iran*[1]

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ABSTRACT

Transformation of rainfall into runoff over an area is a very complex process which exhibits both temporal and spatial variability; runoff in a defined area can be affected by factors such as topography, vegetation, rainfall characteristics and soil properties. This study was conducted to develop an empirical model using the rainfall characteristics and soil properties for predicting runoff from dry-farming lands in a semi-arid agricultural area in Hashtroud, Northwest Iran. Runoff plots (1.83 m × 22.1 m) in triplicate were installed in thirty-six sloped dry-farming lands in the study area. Runoff under natural rainfalls was measured in each plot during a 2-year period. The results showed that runoff for 41 runoff-producing rainstorm events with duration longer than 30 min was largely associated with a rainfall index obtained by multiplying the positive square root of rainfall depth ($h^{0.5}$) by the logarithm of the maximum 30-minute intensity (LogI_{30}) ($R^2 = 0.81$). Runoff significantly varied among the plots ($P < 0.001$), which was considerably related to the effective soil properties ($R^2 = 0.74$), *i.e.*, soil permeability (Per) and aggregate stability (AS). A multiple linear regression model was developed between runoff and the rainfall index ($h^{0.5}\log I_{30}$) and the effective soil properties (AS and Per). Evaluation of the model using 34 runoff-producing rainstorm events that occurred during the next two years resulted in high values of the efficiency coefficient and R^2 (0.88 and 0.91, respectively), which revealed that the model developed in this study could be used in predicting runoff from the dry-farming lands in the semi-arid regions.

Key Words: aggregate stability, dry-farming lands, natural rainfall, rainfall depth, rainfall index, rainfall intensity, soil permeability

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INTRODUCTION

Runoff generation is the original driving force of soil erosion (Le Bissonnais *et al.*, 2005) and nutrient movement from soil surface (Zeng *et al.*, 2008), particularly in arid and semi-arid regions. Almost 39% of land surface of Iran (642 797 km^2) has a semi-arid climate, with an annual precipitation between 200 and 500 mm. In these regions, about 33% of the annual precipitation losses as surface flows (Alizadeh, 2003). In many places, agriculture is mostly performed under rainfed condition and so crop production is wholly dependent on storage of rain water in the soil. Prevention of runoff generation in these regions is essential to conserving soil productivity and supplying water for crop production.

There is a strong demand to develop an accurate and easily used model that can appropriately simulate the process of runoff generation (Lin and Wang, 2007). Many such models have recently been developed (Ma *et al.*, 2009). Nevertheless, modeling runoff in semi-arid regions is also a challenging task because many of the hydrological models developed for humid areas are tuned to a saturation excess mechanism and not to the infiltration excess mechanism that often dominates in dry regions (Faurès *et al.*, 1995).

The process of rainfall transformation into runoff over a catchment is very complex, highly nonlinear, with both temporal and spatial variability (ASCE, 2000). Runoff occurs more commonly in arid and semi-arid regions when rainfall intensities are higher than infiltration capacity of surface soil. Over the last two decades, a large body of knowledge has been built up about the processes of runoff generation in the semi-arid regions (Yair and Lavee, 1985; Abrahams *et al.*, 1988; Martínez-Mena *et al.*, 1998). These studies show that the runoff-controlling factors in semi-arid catchments are different from those which regulate the hydrology of wetter environments. Runoff generation in semi-arid regions is dominated by an infiltration excess mechanism with a short time to final infiltration rates and a fast response due to steep hillslopes with shallow

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soils and lack of vegetation (Greenbaum *et al.*, 2006). Also, surface conditions such as soil crusting and rock pavement (Solé-Benet *et al.*, 1997) are the most relevant factors in these regions.

Runoff generation in a watershed can be influenced by the physical and hydrological parameters of the watershed, topography, vegetation cover, soil properties and rainfall characteristics. Under the same conditions of topography and climate in the watersheds, runoff generation in different hillslopes is solely affected by the rainfall characteristics and soil properties. Many studies have been performed on the relationship between runoff and rainfall characteristics (Jacquin and Shamseldin, 2006; Al-Qurashi *et al.*, 2008; Bahat *et al.*, 2009). Studies on the relationship between runoff and soil properties have been mainly associated with the influences of antecedent soil moisture (Wei *et al.*, 2007; Martínez-Murillo *et al.*, 2013), rock fragment (Cerdà, 2001) and soil management systems (Gómez *et al.*, 2009) on the runoff generation.

More studies done in Iran have focused on the effect of land use change on runoff generation (Saadati *et al.*, 2006), application of the hydrological models in predicting runoff (Rostamian *et al.*, 2008), effect of geomorphologic properties of the watersheds on runoff generation (Abdollahi *et al.*, 2003) and effect of soil particles and surface gravel on runoff generation (Javadi *et al.*, 2004). However, there is no quantitative study to model runoff in dry-farming lands of the semi-arid regions in Iran. Therefore, the objectives of this study were to quantify the influences of the rainfall characteristics (intensity, depth, *etc.*) and soil physicochemical properties on the runoff generation and to develop an empirical model to predict runoff in dry-farming lands of the semi-arid regions.

MATERIALS AND METHODS

Study area

The study was carried out in Hashtroud Township, located in the southern part of East Azarbijan Province, Northwest Iran, from March 2005 to March 2007. The study area was an agricultural zone of 900 km^2 in area (30 km × 30 km) between 37°18′49″ and 37°35′0″ N, and 46°46′5″ and 47°6′5″ E (Fig. 1) in the Gharrangouchai Watershed. The Gharrangouchai Watershed is the largest watershed in Hashtroud, with an area of 2 655 km^2 and a length of 190 km. The latitude in the study area ranges from 1 570 to 1 660 m. The climate is semi-arid with an average annual precipitation of 322 mm and a mean annual temperature of 13 °C. Precipitations mostly occurred in the winter, late autumn and early spring. Agricultural soils are mostly located in 3°–9° slopes and cover about 70% of the land surface. The soils, weakly developed in the profile and often classified as chestnut soils, have a low organic

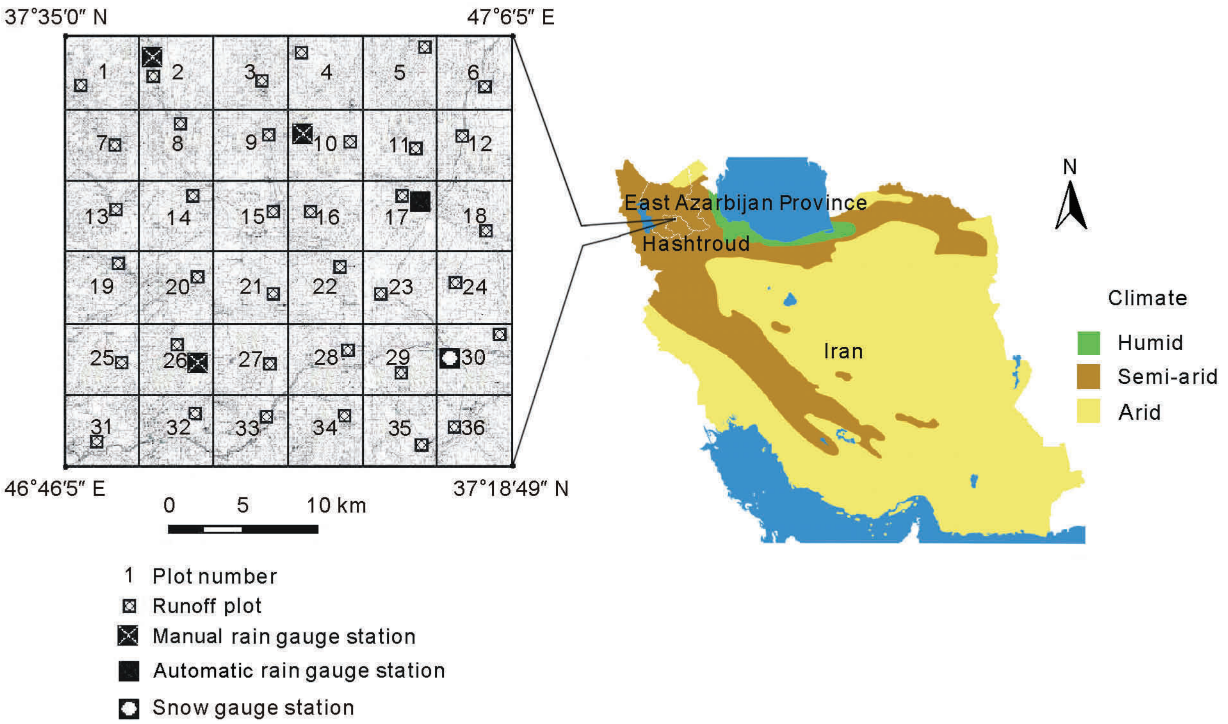

Fig. 1 Location of the study area, rainfall gauge stations and plots used for measuring surface runoff.