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降雨入渗条件下厚包气带土壤水流通量的模拟与分析

Modeling and analyzing water flow in a thick unsaturated zone during precipitation and infiltration

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中文摘要:

降雨较少的半干旱半湿润地区大范围的厚包气带中土壤水运动的研究越来越受到关注，其中厚包气带对降雨补给浅层地下水特征的影响是重要的研究问题。探究厚包气带情形下降雨对浅层地下水的补给作用和机理可为分析人类干扰情况下水文循环规律的变化、合理地制定水资源开发利用规划提供理论依据。本文以北京市大兴区新凤河流域采育镇由GEOPROBE钻机获得的9.6 m厚包气带土壤样品为研究对象，在室内详细测得土壤特性数据的基础上，运用HYSRUS-1D软件模拟55 a降雨入渗条件下的一维土壤水流动态过程，分析土壤水流通量的时空变异特征，探讨用较浅层位（2 m深度附近）的土壤水流通量来估算深层土壤水渗漏量的可行性，旨在为野外裸地厚包气带条件下评价降雨入渗对浅层地下水的补给提供简捷实用的方法。研究结果表明：该地区多年自然降雨条件下的平均土壤水分深层渗漏量为131.03 mm，多年平均降雨入渗补给系数约为0.21。其中，平水年对应的平均降雨入渗补给系数约为0.18。当模拟时段达到55年时，土壤剖面2 m以下的入渗通量几乎不随深度变化而变化。这一实际案例的研究结果对该区域宏观水资源管理和评价具有一定的参考价值。

英文摘要:

Abstract: With more and more attention being received in water flow through the widely distributed thick unsaturated zone in arid and semiarid region, the influence of thick unsaturated zone on the groundwater recharge is of important study. Quantification of groundwater recharge from precipitation under thick unsaturated zone condition can provide theoretic basis for analyzing the hydrological cycle with human disturbance, and reasonably establish water resources development and utilization. Based on the measured soil properties of a 9.6m-deep vadose zone core drilled by GEOPROBE from Caiyu town located in Xinfeng river basin in Daxing district in Beijing, this study focuses on simulation of one-dimensional water transport under 55-year long precipitation time series conditions, analysis of the spatio-temporal characteristics of the water flux and its response to the precipitation and soil texture, and discussion of the feasibility of estimating deep drainage from the shallow water flux. We aim to provide a simple and practical method for evaluation of the contribution of precipitation to groundwater recharge in bare soils. To achieve this, the mechanistic numerical model HYDRUS-1D based on the Richards' equation is used. First, annual precipitation and simulated evaporation, and deep drainage are calculated for the period 1951-2005, with an average annual precipitation of 597.59 mm, an average annual evaporation of 964.38 mm, and an average annual deep drainage of 131.03 mm. Variability in precipitation, ranging from 261.8mm to 1406 mm (Cv=35.72%), was amplified in deep drainage, ranging from 17.54 mm to 699.36 mm (Cv =88.03%), and was reduced in evaporation (Cv=4.58%). Then the long-term monthly average water flux of the soil profile is calculated for the period 1951-2005. The average monthly infiltration rate in the top layer of soil exceeds average monthly evaporation between May and September. Subsequently, long-term (1951-2005) monthly average rainfall, evaporation, and deep drainage for an extreme high (a), high (b), medium (c), and low (d) precipitation region are depicted. The average deep drainage is 103.55 mm in the medium precipitation region (575.76 mm/year average rainfall), with the coefficient of recharge from precipitation of 0.1799, which is lower than the 55-year average coefficient of recharge from precipitation of 0.2138. In general, the highest precipitation months are July and August, and average monthly precipitation exceeds average monthly evaporation during these months except for the low precipitation region. The highest evaporation months are from May to July due to high solar radiation and temperatures in these months. Finally, long-term average soil moisture fluxes in the whole soil profile corresponding to four different time periods (1996-2005, 1981-2005, 1966-2005, 1951-2005 respectively) are calculated, which reveals that the average infiltration rate on soil profile below 2 m keep almost unchanged with the variation of depth between 1951 and 2005.