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Evaluating the effect of different management policies on the long-term sustainability of irrigated agriculture

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ABSTRACT

Rise in groundwater level followed by waterlogging and secondary salinisation has become a serious problem in canal irrigated areas of arid and semiarid regions of the world. A wide range of solutions could be considered to address the problems. But the effectiveness of all the solutions and their combinations cannot be verified with on-farm experiments. Simulation models by way of their predictive capability are often the only viable means of providing input to policy decisions. To combat the problem, the computer based simulation model, SaltMod was applied in a waterlogged area of northwest India in which over 500,000 ha has already waterlogged resulting in reduced crop yield and abandonment of agricultural lands. After successful calibration and validation, several alternative management policies were studied for their long-term impacts on groundwater levels and salinities. The alternative policies revealed that the groundwater levels in the study area would continue to rise in the long-run under the existing conditions. Thus, suitable water management strategies such as changes in cropping patterns with reduced rice area, reduced canal water use, increased groundwater use, and canal lining are suggested to bring the groundwater level down to a safe depth and to prevent further rising of the groundwater level.

1. Introduction

The state of the environment and its proper management is a prerequisite condition for the sustainable development of any country, and India is no exception. Thus, availability of appropriate quantities of water on a reliable basis is essential for improving the quality of life and for sustainable agricultural production (Francis, 1990; Singh, 2014a,b,c). This means that the policies formulated and actions taken must ensure that the developments taking place should not endanger the overall resource and environmental bases of the country, on which the development process itself depends (Singh, 1999; Wichelns and Oster, 2006). Presently, some serious water resources problems exist in parts of north India, in terms of waterlogging and salinity development (Erenstein, 2009; Singh, 2011, 2012a,b, 2014d, 2015a; Singh and Panda, 2013), because conventional agriculture was not traditionally associated with conservation and sustainable resource management (Singh, 2013). Agricultural production methods have to be sustainable in ecological, economic, and social terms, in order to provide food for the burgeoning population (Rasul and Thapa, 2004; Davies and Simonovic, 2011; Singh and Panda, 2012a; Singh, 2012c, 2015b,c), which is expected to increase by another 2.4 billion people globally by 2050 to touch the level of 9.7 billion (United Nations, 2015). Both, growing scarcity of good quality land and water resources and endangered sustainability of irrigated agriculture, dictate that due attention must be given to devise appropriate resource management policies.

A wide range of solutions could be considered to address the problems of waterlogging and salinity. But the effectiveness of all the solutions and their combinations cannot be verified with on-farm experiments (Singh, 2014e). Because specific recommendations derived from site-specific field experiments cannot be generalized to regional level with different eco-hydrological conditions (Singh et al., 2006). Moreover, many problems and prospects associated with a particular management policy are often not recognized until they are well advanced. Simulation models by way of their predictive capability are often the only viable means of providing input to management decisions (Singh, 2015d). These models can help to forecast the likely impacts of a particular water management strategy. The results of simulation studies of existing and proposed management policy, therefore, may form the basis for the identification of appropriate management policies for the future. In recent years, a large number of agro-hydrological models have been used for groundwater and salinity management (Xie and Cui, 2011; Xu et al., 2011; Singh and Panda, 2012b,c; Das et al.,

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2015). These models have gained wide spread acceptance as effective tools to assess the resources problems of irrigated agriculture. Most of these models, however, require input of soil characteristics like the relation between unsaturated soil moisture content, water tension, hydraulic conductivity and dispersivity, which are not easy to measure. They also use short time steps and need at least a daily database of hydrologic phenomena.

Considering the reviews of the past researches and the present necessity as mentioned above an agro-hydro-salinity model SaltMod (Oosterbaan, 2008) which requires seasonal input data that are generally available or that can be estimated/measured with reasonable accuracy, has been used to analyze water and salt balances of an irrigated semiarid area located in northwest India where groundwater level has been rising continuously (Groundwater Cell, 2013a). Srinivasulu et al. (2005) applied the model SaltMod for assessing the effectiveness of subsurface drainage system in the control of waterlogging in a pilot area in Nagarjuna Sagar right canal command of India. Bahceci et al. (2006) tested the model SaltMod with data collected from the Karkın pilot area of Konya-Cumra Plain, Turkey. They evaluated the effects of existing irrigation-drainage practices on root-zone salinity and drain discharge rate. Simulation of subsurface drainage effluent and root-zone salinity in the coastal rice fields of Andhra Pradesh, India was done by assessing the relative performance of artificial neural networks (ANNs) and the model SALTMOD (Sarangi et al., 2006). The study concluded that the SaltMod performed better in predicting root-zone salinity compared to ANNs. Earlier the model SaltMod was applied by Vanegas Chacon (1993), Srinivasulu (2002), and Srinivasulu et al. (2004) for the analysis of salt and water balances in different parts of the world. Determination of the values of the unknown variables of SaltMod by fine-tuning during calibration, statistical evaluation of the model, and the assessment of the long-term effect of different water management policies on the groundwater levels and salinities are the specific objectives of this study.

2. Materials and methods

2.1. Problems of the water resources

The State of Haryana is located in northwest India and covers a total area of 44,212 km^2, of which about 98% lies in an alluvial plain between the Ghaggar and Yamuna rivers. Since the introduction of the 'Green Revolution' during 1970s, nearly all the cultivable land in the State is under rice-wheat dual cropping system, which requires more water than is available. As a consequence, groundwater development in some districts is more than the replenishable groundwater recharge and a large part of the North, East and South Haryana (except central and western part) is facing the problem of falling groundwater table. However, in the study area, watertable is rising, as it is characterised by a geological depression, which causes groundwater movement towards its centre (Groundwater Cell, 2013a). In the State, the groundwater level is primarily declining in areas with fresh and marginal quality groundwater. In contrast, rising groundwater tables are registered in areas where groundwater is of poor quality. An estimated 500,000 ha of the State are waterlogged and unproductive and the size of the waterlogged area is increasing and creating hydrologic imbalances (Singh et al., 2010). Within the State there can, thus, be significant local variation in water management problems, with declining aquifers, waterlogging and salinisation existing side by side (Datta and de Jong, 2002; Bhalla, 2007; Erenstein, 2009). The key issues related to water management in the study area are scarce and unreliable rainfall, high evaporative demands, poor groundwater quality, rising groundwater levels, light-textured soils with low water holding capacity. Besides, factors like delay and failure of monsoon, and conveyance losses from irrigation system are further affecting the crop production in the area.

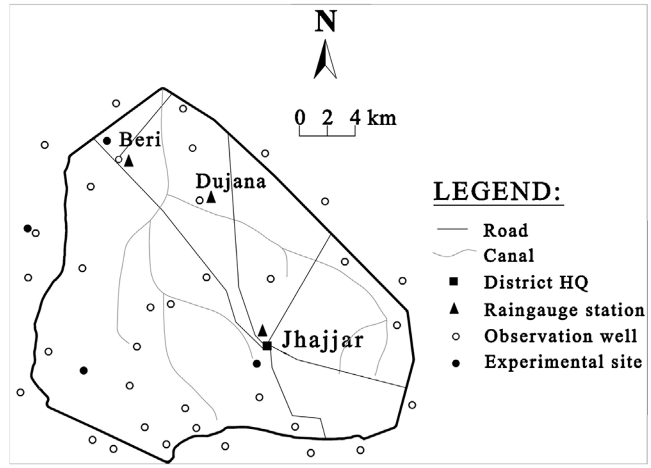

Fig 1. Location map of study area with rain gauge stations and observation points.

2.2. Study area

The Jhajjar Distributary is located in Haryana State of India between 28°33′N to 28°38′N latitude and 76°35′E to 76°41′E longitude and covers about 7759 ha. Administratively, the area is in Jhajjar district of Haryana and situated at the tail end of the

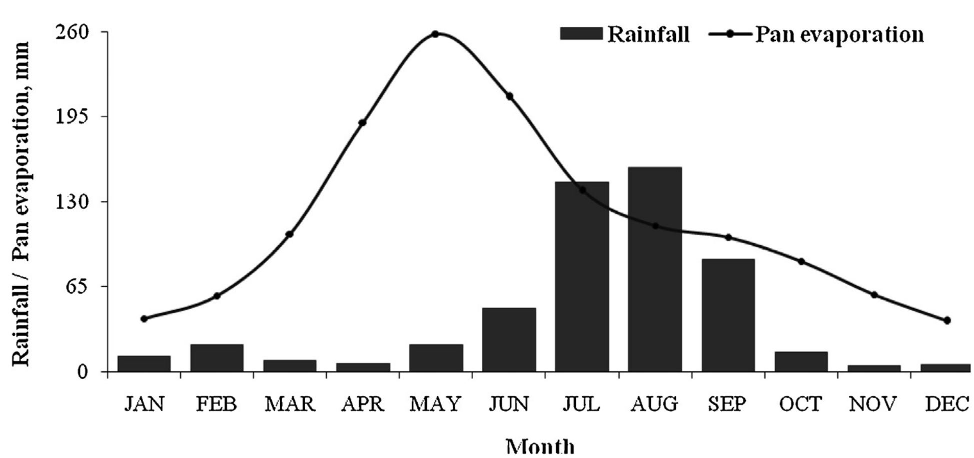

Fig. 2. Distribution of mean monthly rainfall and pan evaporation.