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Quantifying risk for water harvesting under semi-arid conditions Part II. Crop yield simulation

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Abstract

Risk assessment of maize yield was carried out using a crop growth model combined with a deterministic runoff model and a stochastic rainfall intensity model. These were compared with empirical models of daily rainfall–runoff processes. The combination of the deterministic runoff model and the stochastic rainfall intensity model gave more flexible performance than the empirical runoff model. Scenarios of crop simulation included production techniques (water harvesting, WH, and conventional total soil tillage, CT) and initial soil water content at planting (empty, half and full). The in-field water harvesting technique used in the simulation was a no-till type of mini-catchment with basin tillage and mulching. The lower the initial soil water content at planting, the greater the yield difference between the WH and CT production techniques. With the low initial soil water content at planting, the WH production technique had up to 50% higher yield compared to the CT production technique, clearly thus demonstrating the superiority of the WH production technique. Under all the variations in agronomic practices (planting date, plant population, cultivar type) tested, the WH had a lower risk than CT under these semi-arid climatic conditions (i.e., WH increased the probability of higher crop yields).

Keywords: In-field water harvesting; Maize; Rainfall intensity; Runoff; Crop simulation

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1. Introduction

In semi-arid climatic regions of the world, it is important to increase crop productivity with rainwater harvesting because these areas face water scarcity and therefore food insecurity. Many types of water harvesting techniques have been reported (Boers and Ben-Asher, 1982; Frasier and Mayers, 1983; Cater and Miller, 1991; Hensley et al., 2000; Wiyo et al., 2000), however, field experiments for assessing those systems are very expensive and laborious. As a result, several models of water harvesting and comprehensive models of rainfall–runoff-yield systems have been developed (Gould and Nissen-Petersen, 1999; Young et al., 2002). For example, Young et al. (2002) introduced the comprehensive model simulator ‘‘Parched-Thirst’’, which generates rainfall intensity (if no data is available), estimates runoff using a water balance model, and then predicts crop yield. If tools such as these are used, it can be possible to assess risk of crop production with water harvesting techniques (Sanchez et al., 1995). In South Africa, during the last decade in-field water harvesting experiments have been conducted at Glen (Hensley et al., 2000). Hensley et al. (2000) introduced a no-till type of micro-catchment and basin covered by mulch as shown in Fig. 1. They carried out field trials of maize production systems during three growing seasons (1996/1997, 1997/1998 and 1998/1999) showing yield advantages from the water harvesting (WH) technique over a conventional total soil tillage (CT) production technique in field experiments (on-station and on-farm experiments) in a semi-arid region of South Africa.

In order to quantify risk for different production techniques, crop growth modelling, normally run on a daily basis, can be used as an analytical tool. However, an estimation of daily runoff is a prerequisite for the analysis. In general, preventing runoff during rainfall increases the effective rainfall water available for conventional crop production, while adding water from a runoff area to rainfall gives additional water, which can be used by crops in water harvesting crop production system. This modelling exercise attempts to simulate the WH system (Fig. 1) that was implemented in the field experiment to illustrate

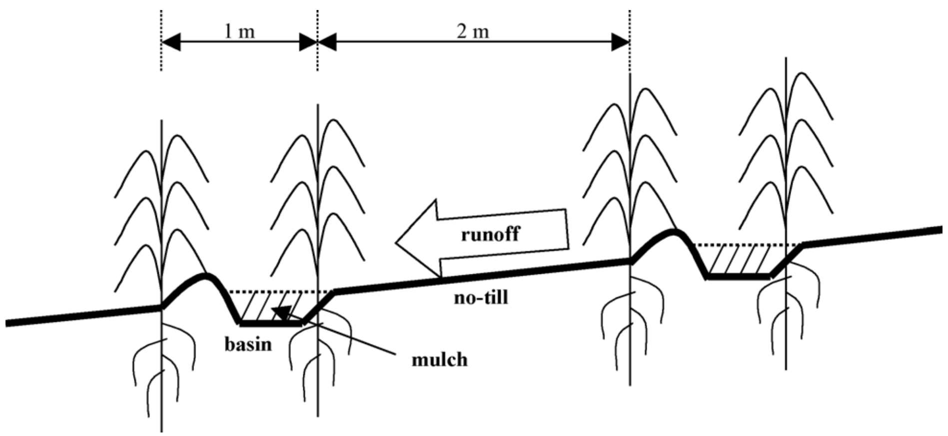

Fig. 1. A diagrammatic representation of the water harvesting/basin tillage/no-till/mulching (WH) production technique (after Hensley et al., 2000).