

Use of the FAO AquaCrop model in developing sowing guidelines for rainfed maize in Zimbabwe

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ABSTRACT

This paper presents a procedure in which the water-driven water productivity model AquaCrop was fine-tuned and validated for maize for the local conditions in Zimbabwe and then applied to develop sowing management options for decision support. Data from experiments of 2 seasons in Harare and from 5 other sites around Zimbabwe were used for the local calibration and validation of AquaCrop. Model parameters such as the reference harvest index (HI_0); the canopy growth coefficient (CGC); early canopy decline and normalised biomass water productivity (WP_b) were adjusted during model calibration. Model performance was satisfactory after calibration with a Nash-Sutcliffe model efficiency parameter ($EF = 0.81$), $RMSE = 15\%$ and $R^2 = 0.86$ upon validation. To develop sowing guidelines, historical climate series from 13 meteorological stations around Zimbabwe were used to simulate maize yield for 6 consecutive sowing dates determined according to criteria applicable in Zimbabwe. Three varieties and typical shallow and deep soil types were considered in the simulation scenarios. The simulated yield was analysed by an optimisation procedure to select the optimum sowing time that maximised long-term mean yield. Results showed that highest yields depended on the climate of the site (rainfall availability), variety (length of growing cycle) and soil depth (soil water storage capacity). The late variety gave higher mean yields for all sowing dates in the maize belt. Staggered sowing is recommended as a way of combating the effects of rainfall variability and as an answer to labour constraints.

Keywords: biomass water productivity, AquaCrop, maize sowing dates, crop modelling

INTRODUCTION

The global population is projected to continue on an upward trend (FAO, 1996; Mpande and Tawanda, 1998), more so in sub-Saharan Africa where food deficit is already a significant challenge (Pinstrup-Andersen et al., 1999). Competing demands for both freshwater and land use, such as from industry and municipalities, as well as environmental problems such as pollution, will limit future extension of both freshwater for irrigation and the cultivated land area. With limited room for expansion of both agricultural land and the irrigated portion of the arable land (Rockström and Baron, 2007), additional food production will have to come from intensification of production in rainfed farming systems. Rockström et al. (2003) showed that it is possible to at least double rainfed staple food production by producing more 'crop per drop' of rainwater. It is therefore necessary to explore ways of increasing water use efficiency in rainfed agricultural systems.

Climate variability has been identified as the major constraint to agricultural productivity in southern Africa, and hence reducing the risk associated with climate variability has a high potential for increasing productivity in Zimbabwe (Phillips et al., 1998). Despite commanding a large share of the annual grain output, rainfed production of maize in Zimbabwe is largely unstable (Mhizha, 2010). The fluctuations

echo in the availability of food in the country, often with a telling effect on the economy as resources are channelled towards securing food to avert starvation, resources which would have otherwise gone to other economic sectors for development. The instability in rainfed production is largely credited to availability of rainwater, which itself shows wide variability in both total amounts and seasonal quality (Rockström and Barron, 2007). Rainfall variability, especially the less well defined onset of the rainy season has increased in the recent past possibly linked to climate change. The start and end of the rainy season defines the length of the rainy season which strongly determines the success or failure of rainfed crops. In addition, the quality of the growing season, as indicated by the length and severity of within-season dry spells, will also influence the yield gap and can often cause total crop failure (Geerts et al., 2006; Phillips et al., 1998). While agricultural water management has largely succeeded in maximising rainfall infiltration through soil and water conservation, the challenge of how to cope with dry-spells, short periods of water stress during crop growth, remains largely unsolved (Fox and Rockström, 2003). Because false planting dates requiring replanting are increasingly common in Zimbabwe (Raes et al., 2004), there is an increasing demand for sowing strategies that minimise risk of total crop failure, such as staggered planting.

Judicious management decision making, such as planting dates and fertiliser application rates, can contribute to increased yields under rainfed conditions. Management decision support for rainfed farming systems is a challenge for resource-poor communities such as subsistence farmers in Sub-Saharan Africa. Optimum management practices, such as planting date, cultivar selection, fertilisation, or water and

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