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# How much can irrigation reduce climate-induced risk to sustainably intensifying maize production in southern Africa?

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## Introduction

Maize is the staple crop in Southern African drylands, but smallholder farmers are far from achieving potential yields. Climate change projections warn that low and variable yields will be exacerbated, making farming riskier without adaptation. Drought-tolerant cultivars (Cairns & Prasanna, 2018), balanced site-specific fertilisation (Rötter & van Keulen, 1997) and adjusted sowing (Rapholo et al., 2019) could reduce yield gaps and improve crop system resilience.

We examine the extent to which irrigation can reduce risk and support Sustainable Intensification (SI) of maize production in Southern African drylands. Various SI and adaptation options are studied in Limpopo Province, Republic of South Africa (RSA), where ca. 55% of households are far from food secure (de Cock et al., 2013) hypothesising that SI of maize production cannot be achieved without irrigation.

## Materials and Methods

Two sites were chosen within the Limpopo Province that exemplify two ends of the soil-water holding capacity and rainfall spectrum: (i) Syferkuil, University of Limpopo, Mankweng, and (ii) University of Venda, Thohoyandou. Syferkuil has low-rainfall and limited soil conditions, with averaged total annual rainfall of 491 mm (1980-2010). The soil is a sandy clay loam, and has a plant available water capacity (PAWC) of 55 mm. Venda receives higher annual rainfall (847 mm) and is a well-drained sandy loam (PAWC of 143 mm).

Maize growth was simulated with the APSIM model (Holzworth et al., 2014) from 1981 to 2010. The response of several maize cultivars, including high-yielding (Hybrid614), and drought-tolerant (Katumani) cultivars was tested. Three irrigation levels (no irrigation: rainfall; deficit: 82 mm; and full: 149 mm) (averaged over 1981-2010), and three fertilisation treatments were applied (0, 90, and 180 kg/ha mineral N as urea; two intervals: sowing and 60 days after sowing).

## Results and Discussion

Maize yields increased from 0 to 90 N kg/ha, with only a slight increase from 90 to 180 N kg/ha. Deficit irrigation led to strong yield gains compared to no irrigation, with only slight additional increases under full irrigation. Our simulation experiments address and quantify the point at which yield gains cease. They also highlight the most promising options for farmers from an economic point of view with current and expected maize prices as well as input costs under climate change projections and anticipated socio-economic trends.

Several scenarios were considered for input costs, such as energy and fertiliser vs. maize prices, as well as possible fluctuations to calculate gross margins and variable risk, for both the baseline and future periods. Energy price turned out to be most influential on economic viability for both periods.

## Conclusions

Crop simulation results from two contrasting sites in the Limpopo Province prove deficit irrigation to be crucial to reduce maize production risks and gain benefits from yield-increasing inputs, such as N fertiliser. Risk-oriented management strategies that include adequate and economically viable combinations of irrigation, fertiliser and suitable cultivars are needed. It is vital to identify when irrigation, in particular, is a 'pre-condition', which can be evaluated *ex ante* using appropriate crop model simulation experiments.

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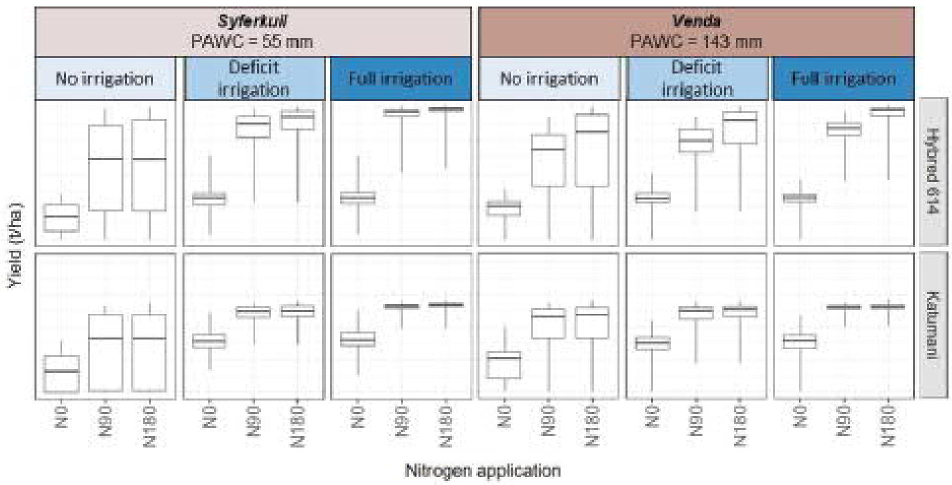


Figure 1. Maize yield of two cultivars (Hybrid 614: 136 and 159 days; and Katumani: 81 and 94 days in Venda and Syferkuil, respectively) from Venda (good soil) and Syferkuil (poor soil), with the respective Plant Available Water Capacity (PAWC) (water storage capacity of the soil) for each site. Three levels of irrigation (no: rainfall; deficit: 82 mm; and full: 149 mm), and three levels of N application (0, 90, and 180 kg/ha mineral N as urea in two intervals: sowing and 60 days after sowing) were applied for the weather data used (1981-2010). Each box represents a sample number of 30. The three horizontal lines indicate the 75% percentile (up), median (solid line across boxes) and 25% percentile yield (bottom); the upper and bottom bars outside the boxes show the maximum and minimum values respectively.

**Keywords:** Crop modelling, food security, risk management, sustainable intensification, water use.

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