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Supporting information for “optimal control for precision irrigation of a large-scale plantation”*

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Supporting Information for "Optimal Control for Precision Irrigation of a Large-Scale Plantation"

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Abstract
This document contains supplementary material for the paper "Optimal control for precision irrigation of a large-scale plantation," by R.C. Kassing, B. De Schutter, and E. Abraham, *Water Resources Research*, vol. 56, no. 10, Article e2019WR026989, Oct. 2020.

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Introduction

This supporting information provides material that supports the evapotranspiration estimation method proposed by modeling the canopy cover development using remote-sensing data from a sugarcane plantation in Xinavane, Mozambique. Furthermore, for reasons of reproducibility the AquaCrop-OS parameters for the soil, crop, and management are available from a publicly accessible repository, see:
`http://doi.org/10.4121/uuid:4fb3a35f-1786-45ee-a2f8-65a391fa86d0`.

Using NDVI data as a measure of canopy cover

Our proposed evapotranspiration model (Eq. (11) of the manuscript) uses NDVI as a measure of how the transpiration will evolve over the growth cycle of the crop. The NDVI essentially measures how well the near-infrared and visible red range of the light spectrum are reflected by the ground. This correlates strongly with chlorophyll content (Gitelson & Merzlyak, 1997), biomass (Goswami et al., 2015; Shippert et al., 1995), evapotranspiration (Trout et al., 2008; Kamble et al., 2013) and leaf area index (Carlson & Ripley, 1997). Furthermore, most land-grown crops use photosynthesis to produce food to survive and thus use more water as they grow (so also transpire more water).

Canopy cover curve development model from real NDVI data

In our work, the Level 2A reflectance data of band 4 (red) and band 8a (narrow near-infrared) from Sentinel-2 are used to calculate the Normalized Difference Vegetation Index (NDVI). This resulted in 28 NDVI images for the study area for the period from April 2016 to July 2018. Furthermore, for each plot the planting and harvesting data of the last five years are made available by Tongaat Hulett. Next, the data from 10 out of 24 fields were selected (XNC19, XND18-20, and XNE18-23, see Figure 1), other fields were excluded due to planting and harvest dates being inconsistent with NDVI data. For each selected plot the NDVI measurement points in growing days were converted to thermal time in Cumulative Growing Degree Days (CGDD) using the daily average temperature data available from the local weather station. A maximum temperature of $T_{\text{upper}} = 32°$ Celsius and a base temperature of $T_{\text{base}} = 12°$ Celsius were used, see Eqs. (6) and (7) in Section 2.1 of the manuscript. By using thermal time we correct for the effect of temperature variations on the crop development of the sugarcane over the growing cycle, so we can more accurately predict the evapotranspiration (Eq. (11)). The NDVI–CGDD data points are fitted with a second-order polynomial using the robust Least Absolute Residuals (LAR) method, see Figure 2. The LAR method finds a curve that minimizes the absolute difference of the residuals, rather than the squared differences. Therefore, extreme values have less influence on the fit.

This curve can be used to correct the predicted reference crop evapotranspiration for the expected crop growth stage (effectively the CGDD) of the individual fields.

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Acronyms

CGDD Cumulative Growing Degree Days

FAO Food and Agriculture Organization of the United Nations

LAR Least Absolute Residuals

NDVI Normalized Difference Vegetation Index

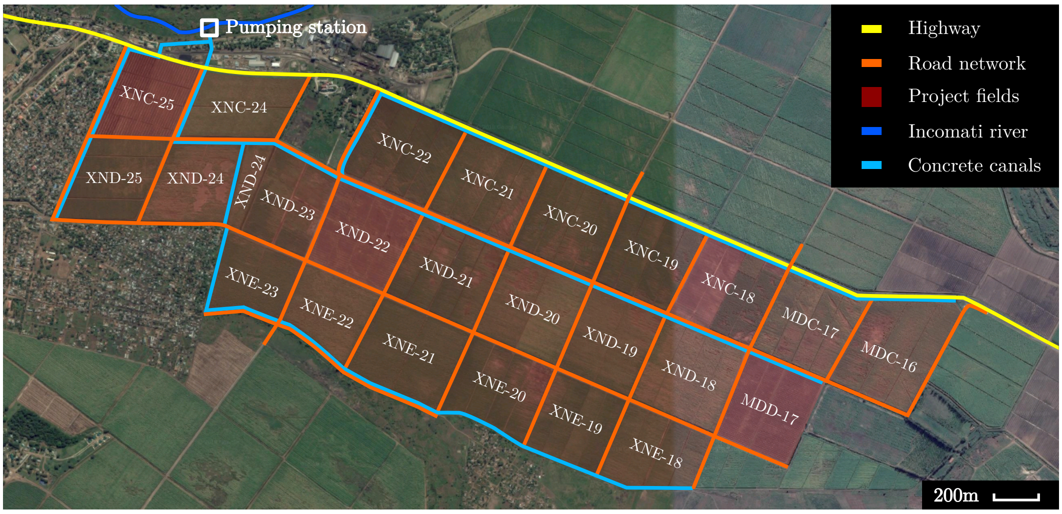

Figure 1. Detailed layout of the Xinavane sugarcane plantation.

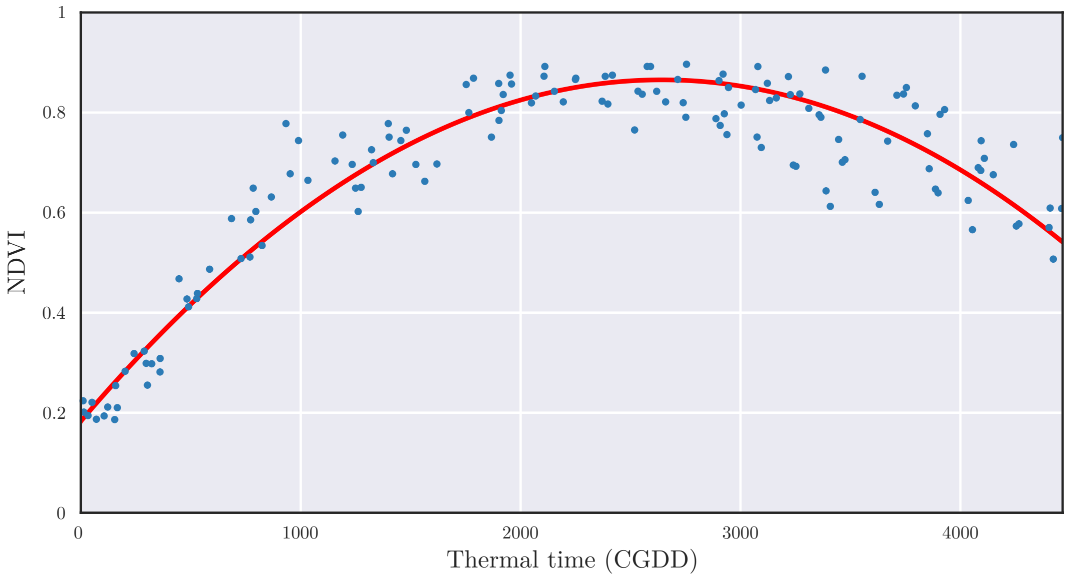

Figure 2. The NDVI data points are fitted by a quadratic curve using the robust LAR method. This fitted model provides us with a real world example in which the evolution of NDVI data tracks the canopy development over the growth season, which motivates our modeling approach in Section 2.1.2 of the manuscript. Similarly to this figure, see also Figure 5 of manuscript, which closely tracks the shape of the crop factor curve of sugarcane described by the FAO.