POLICY BRIEF

September 2020
The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

WATER RESEARCH COMMISSION

Investigating the water use of biofuel crops

A significant expansion of agricultural production is required to meet the demands for feedstock required by biofuel manufacturers. South Africa is a water-scarce country. Thus, the greatest challenge facing the biofuel industry will be to increase crop production using less water. A recently completed Water Research Commission (WRC) project investigated the water use of strategic biofuel crops in order to determine best agronomic practices for maximising attainable yield.

Background

The project on water use of strategic biofuel crops was informed by recommendations from previous studies, as well as by policy related to biofuel production in South Africa, such as the policy paper released by the Department of Water and Sanitation (DWS, 2016) which supports the cultivation of biofuel feedstocks under rainfed conditions.

In addition, the draft Biofuel Regulatory Framework, published in 2014, highlighted soybean and sorghum as reference feedstocks to represent the production of biodiesel and bioethanol, respectively. It also strongly supported the inclusion of smallholder farmers in the biofuel value chain.

The study was also informed by the significant expansion of agricultural production required to meet the demands for feedstock required by biofuel manufacturers, yet South Africa is a water-scarce country. Thus, the greatest challenge facing the biofuel industry will be to increase crop production using less water (i.e. improve crop water use efficiency).

In addition, the government is promoting the use of unproductive arable land for feedstock cultivation under rainfed conditions. Research is therefore required to assist smallholder farmers to improve crop yields, thereby increasing the efficient use of available water resources. Research is also required to facilitate the participation of smallholders in the biofuel value chain.

On 13 December 2019, Cabinet approved the draft Biofuel Regulatory Framework, which allows for the implementation of the 2007 Biofuel Industrial Strategy. The framework was amended in January and published on 7 February 2020. The research presented in this document, together with that published by the previous project, will provide government (in particular the Department of Agriculture, Land Reform and Rural Development, and the Department of Human Settlements, Water and Sanitation) with valuable information and knowledge to assist with and hopefully guide the implementation process.

The WRC project aimed to assess the water use efficiency of soybean and grain sorghum biofuel feedstocks at both the smallholder and commercial farming scale, but with an emphasis on soybean. The knowledge gained from the field trials facilitated the development of agronomic guidelines for feedstock production, particularly for smallholder farmers, and the validation of the modelling approach to estimate the water use and yield of these two feedstocks.

Major outcomes

Agronomic requirements and production guidelines for both crops were synthesised from the available literature and supplemented with knowledge gained from the field trials. For example, the application of mulch should be considered by smallholder farmers, especially under rainfed conditions where water is a major limiting factor.

Line-wire thermocouples installed at canopy height.

Cultivar selection aims to reduce risks by avoiding, for example, drought periods during the most critical growing stages of the plant growth, such as flowering and seed set. Many factors need to be considered when selecting a cultivar for a particular location such as the target yield, intended purpose (e.g. biofuel production), expected planting date and season length, weather conditions likely to be experienced over the growing period and seed availability. The Biofuel Regulatory Framework noted that government will promote the use of drought-resistant cultivars.

Under rainfed conditions, rainfall variability is an important determinant of crop yield. Thus, planting date selection is critical to ensure that critical growth stages do not coincide with dry spells. Based on an analysis of 50 years of rainfall and temperature data for each quinary sub-catchment, the first planting date: (i) could not be determined for 26.2% of the quinary sub-catchments, thus indicating their unsuitability for crop production; (ii) occurs in either November or December for the majority of quinary sub-catchments; and (iii) occurs in October and January in a few quinary sub-catchments.

Maps showing the spatial variability in planting date are presented in the final report of the project. However, weather is known to vary between growing years, affecting the selection of planting dates. Hence, it is acknowledged that planting dates should be determined using climate forecasts, rather than using historical data.

Access to seasonal weather forecasts is recommended to aid farmers' management practices, planning and the selection of planting dates.

Enterprise budgets were developed to determine the profitability of feedstock cultivation and were based on the specific agronomic requirements of each crop. The budgets present costs (both fixed and variable) and income estimates for producing a hectare of soybean at Baynesfield (a commercial farm) and grain sorghum at Swayimane (a rural farming environment).

The break-even yields estimated for soybean and sorghum were 1.77 and 3.43 t ha-1, respectively. For sorghum, costs were scaled up from the 2017/18 research trial to a hectare, which can potentially drastically distort the budget.

Observed needs from the project

For the soybean trial conducted in the first season, parameter values for the soil-water balance (SWB) model were selected for soybean cultivar LS6161R and compared to those derived by Dlamini (2015) for six other soybean cultivars. Leaf Area Index was then simulated using the SWB model for the control (non-mulched, fully fertilised) treatment.

Although the model oversimulated the LAI, model performance was considered adequate. The SWB was also used to simulate biomass production, with a tendency to overestimate observations. The SWB did not adequately simulate the profile water content and simulated a much drier soil profile, especially at mid-season and at harvest.

A full calibration of AquaCrop was not possible using data from the field trials as they were rainfed and thus water stressed.

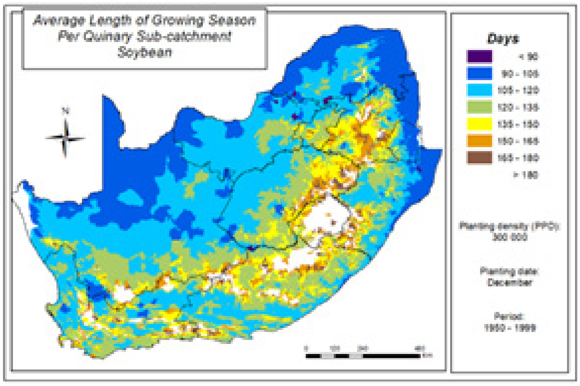
Published model parameters for both soybean and grain sorghum were obtained from a literature review. It is clear that more studies pertain to soybean than to sorghum.

Most of the soybean studies performed a partial model calibration to adjust certain cultivar-specific parameters. Hence, a similar approach was adopted in this project.

For sorghum, certain crop parameter values were obtained from the literature. Model calibration was then validated by comparing simulated against observed yields.

A new approach was adopted in this project to derive monthly values of interception loss per rain day from measurements of monthly LAI for the two selected feedstocks. Two methods were used: the Von Hoyningen-Huene equation and the variable storage Gash model.

Major findings



The crop model provided estimates of crop evapotranspiration (ET), yield and WUE for each quinary catchment. Four national crop model runs were performed for each crop, i.e. for two planting dates and two planting densities. The yield maps developed from AquaCrop output clearly highlight low and high potential areas for soybean and sorghum production. Large parts of the country's interior region, especially towards the western areas, are too dry for crop cultivation under rainfed conditions. Other parts along the Drakensberg Escarpment and in the Lesotho Highlands are too cold for crop production.

The maps of WUE indicate that sorghum is more water use efficient than soybean due to higher sorghum yields. The maps also show that changing the planting date had a greater impact on crop production than changing the planting density.

The higher planting density usually produced a greater crop yield, as expected. Due to the speed improvements made in running AquaCrop at the national scale, the scene is set to consider other scenarios involving different planting dates and plant populations. However, model output should support decision-making processes and not be used to derive absolute recommendations for best management.

This project has significantly contributed to improving the methodology typically used to assess the impacts of land use change on hydrological response using the ACRU model. To recap, the main contributions are as follows: Crop coefficients representing fallow conditions were measured and used in modelling the hydrological impact of crop production.

Water use coefficients representing soybean and grain sorghum were calculated from crop model output. Monthly interception loss values were modelled using a new and improved technique.

A new baseline land cover was used to assess the hydrological impact of biofuel crop production on downstream water availability. The time required to run AquaCrop and ACRU at the national scale has been significantly reduced.

Recommendations

The effects of fertilization and inoculation on crop yield were not significant, which was not expected. The trials should therefore be repeated in other agro-ecologies and over multiple seasons to determine if the same result is obtained. When measuring crop water use, the new surface renewal method implemented in this project should be used and not the simple water balance approach. The means the trials should be at least 80 x 80 m in size. The water use and yield of PAN1521R should be determined, as this cultivar is suited to a wide range of growing conditions.

In the future, a full crop model calibration should be performed for both soybean and sorghum. This will require irrigated trials to obtain growth and yield measurements under optimum irrigation, deficit irrigation and rainfed conditions. Four planting date options (15 October, 15 November, 15 December and 15 January) should be considered for each national model run. AquaCrop outputs canopy cover development on a daily basis, from which LAI could be estimated, and then used to derive interception loss via the modified Gash model.

The quinary climate database needs to be extended beyond 1999 to 2019 (i.e. by an additional 20 years). National assessments of hydrological and agricultural response to climate variability, based on the additional 20-year record, would provide a better assessment of risk. This is due to the anthropogenically induced changes in extreme climatological events that have occurred from 2000 onwards.

In addition, the quinary soils database needs to be updated by assigning soil properties (e.g. depth and texture) to each terrain unit within a particular quinary sub-catchment. From this, soil water retention parameters could be estimated, thus improving the spatial accuracy of the soils database.

Related report:

Water use and yield of soybean and grain sorghum for biofuel production (**WRC Report no. 2491/1/20**). For more information, contact WRC Executive Manager, Dr Sylvester Mpandeli, Email: sylvesterm@wrc.org.za