FINAL REPORT

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Optimization of an existing crop growth simulation model for soybean production

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Executive summary

The CROPGRO-Soybean model also referred to as SOYGRO, which is an integrated model within the Decision Support System for Agrotechnology Transfer (DSSAT) framework, was developed in the USA under their specific conditions. Early in the 1990's, American and South African scientists staged a collective team effort in order to adapt the model for South African conditions. A significant improvement in the model's prediction on soybean (*Glycine max* L. Merr.) growth for South African conditions was achieved over the next six years. Adaptations and corrections were mainly focused on the effects of temperature on phenology aspects. In order to verify and calibrate such a system some criterion is needed to evaluate performance. It is generally accepted that the ultimate test of a system is the accuracy with which it describes the actual system, thus requiring comparison of the estimate and the final data. The objectives of this study were to improve the model's simulation results through calculation of genetic coefficients for commercial soybean cultivars and measurement of soil water limits specifically related to soybeans. Simulated yield results will be compared with results of soybean production systems and overall guidelines constructed from simulations on natural resource suitability for soybean production in South Africa.

In order to calibrate the SOYGRO model for genetic coefficients a calibration program (NETCAL) was developed using the SIMPLEX method. In this procedure SOYGRO is seen as a detached non-linear function that has to be calibrated. In the process measured yields are used as reference from which genetic coefficients are determined through a process of iteration thus, continuously changing values until the best fit with a measured yield is obtained. Water-holding limits are one of the most profound factors that affect simulation accuracy. Quantification of these limits, which consist of the drained upper limit (DUL) where all excessive water has drained from the soil profile through gravitational power and the lower limit (LL) where water stress occurs, are essential in determining available or plant extractable soil water. DUL is a pure soil dependable function, an algorithm was developed using existing data of the relation between clay content and soil water regimes. Onset of stress was measured with automated infrared thermometry as the difference of canopy temperatures between irrigated and dryland plots. A sudden change in canopy

temperature difference between stressed and non-stressed plots gave an indication of the onset of stress. Soil water content at this point was correlated with clay content and the function used to calculate LL. With genetic coefficients and soil water limits quantified evaluation of simulated results commenced. Measured results from the national cultivar trials were used for a three-year period (1998/99 – 2000/01) as term of reference. Localities were chosen according to data comprehensiveness for all relevant input and output data. In decision support yields were simulated for different soil-climate scenarios. Soils consisted of five different effective depths, six different average clay contents and five rainfall scenarios. This was done for cooler and warmer areas as an indication to the effect of temperature. Using long term national cultivar trial and simulation results a yield potential map was constructed with the aid of GIS technology.

Accuracy of SOYGRO's performance was improved significantly, mostly through the configuration of genetic coefficients and quantification of water limits. Comparison of 20 cultivar's simulation results in 2004 against those of 6 cultivars in 1995 indicates an improvement of simulated compared to measured yields. In 1995 results indicated the model to over-estimate yields at low potentials and under-estimate it at high potential conditions. The same is true for the current results, however, the average margin of deviation has decreased significantly. The model, however, did not quite meet the objective set out in the original project proposal of predicting 80% of the time at 75% accuracy. Overall the current accuracy is set at 80% of the time at 70% or better accuracy. The difference in specific cultivar behaviour ought to be taken into consideration. Due to the fact that certain cultivar's genetic coefficients are more accurate than others the level of model performance will also vary according to cultivars. For example, yield simulation performance for A5409 will be 84% of the time at 80% or better accuracy. When separating simulation versus measured correlation coefficients into cool, moderate and warm areas it became evident that simulations for the cool areas are the limiting factor in the overall probability of accuracy. Cultivar yields simulated poorest for the cool areas include LS 555, MARULA, MARUTI and SCS 1. Of these LS 555, MARULA and MARUTI are medium to long growers and SCS 1 is predominantly a long seasonal grower that is not suitable to cooler areas. The model, however, should be able to simulate these responses fairly accurate. This suggests that either some genetic coefficients for the minority of cultivars are not quantified satisfactory or the phonological sub-routine in the model is not adequately adapted for South African conditions. The fact that most cultivar's simulation results compare good with measured yields in moderate and warm areas rather suggests the latter statement to be most relevant. Through grouping of cultivars according to growth duration and comparing it with temperature zones the same result is observed that the long grower's response are simulated the worst under cool conditions. Contrary to that, it is not a recommended practice to plant cultivars in environmental areas unsuitable for them.

Because of the relative large number of genetic coefficients needed for soybean growth simulation the iteration method used in computer generating coefficients proved to be highly effective. Generated genetic coefficients together with improved water limits significantly improve the model's ability to simulate actual production systems. In general, the model simulates on average much more accurate than previous versions. It can be used with much higher certainty as a tool to access management options like planting date, population differences etc. for specific soil and climate conditions. It is also useful in potential determination and economic assessments. Supportive tools created with the model could be useful if applied together for specific locations of which soil and climate characteristics are known.