EXECUTIVE SUMMARY

There is much evidence to support the contention that reliable plant growth models can make an important contribution towards promoting improved rainfall use efficiency, and therefore sustainable land use and food security. It is known that the water balance subroutines of the main crop models currently used in South Africa are relatively unreliable. The aim of this project was to attempt to improve their reliability, and then use them to make long-term predictions to quantify risk. The following were the detailed aims as set out in the original project:

1. To obtain the necessary data over a period of three years at eight benchmark crop ecotopes to test and adapt selected crop models so that they are capable of making reliable long-term predictions of the water balance and of crop yield.
2. To use the calibrated models together with long-term climatic data, to obtain for each benchmark ecotope,
   (a) long-term cumulative distribution functions of yield - to serve as quantitative estimates of risk;
   (b) long-term predictions of runoff and deep drainage - to provide surface and subsurface hydrological information.
3. To accumulate knowledge about how to adapt crop models to give reliable results for ecotopes with a wide range of characteristics - to improve the efficiency of extrapolation to unknown ecotopes.

The following benchmark ecotopes were selected for the study. The first name of the ecotope, because it is geographical, provides for most readers a general description of prevailing climate, and the second name identifies the soil in terms of the South African Soil Classification System. The maize ecotopes were Setlagole/Clovelly, Wolmaransstad/Hutton, Kroonstad/Avalon, Bethal/Hutton, Bethal/Avalon and Ermelo/Longlands. The wheat ecotopes were Bultfontein/Clovelly and Petrusburg/Bloemdal. Yield and detailed water balance measurements were made at each ecotope over three growing seasons.

Comparisons between measured and simulated results showed that although both the DSSAT3 and PUTU maize and wheat models sometimes gave reliable yield predictions, they were also sometimes very unreliable. Soil water content predictions were better than those of yield, but also at times unsatisfactory. Adjustments are needed to improve reliability. The following are important model weaknesses that have been exposed: (a) the lack of a subroutine to deal with waterlogging in maize ecotopes; (b) the lack of a subroutine for the absence of secondary roots in wheat; (c) the inability of PUTU to predict high yields on the Bethal/Hutton and Bethal/Avalon ecotopes; (d) the excessive maize root water extraction rate frequently simulated by DSSAT3 during the last part of the growing season; (e) unsatisfactory runoff subroutines for both models; (f) unsatisfactory stress prediction subroutines, especially in DSSAT3; (g) the lack of a subroutine to cater for lateral water movement in the root zone.

Due to frequent waterlogging at some of the maize ecotopes it was possible to make some valuable observations about the ability of maize to withstand this hazard. Where a water table remained at a depth of about 500 mm at the Ermelo/Longlands ecotope for most of a

growing season the yield was very poor. At the Bethal/Avalon ecotope where the water table was maintained at a depth of about 700 mm for the first 75 days of the growing season, there were virtually no adverse effects, the final yield being 10 575 kg ha^{-1} . A provisional threshold water table depth for maize can therefore be set at about 600 mm.

Long-term cumulative functions (the same thing as cumulative probability functions or CPF's) of yield were computed as follows. Four CPF's were computed for each ecotope using each of the following root zone water contents at planting viz. ¼, ½, ¾, and full. This was done to avoid the problem of not knowing what the actual water content was during each of the growing seasons for which rainfall data was available. Predicted grain yields (t ha^{-1}) at 50% probability, starting with a full root zone at planting, and presented in the order of the ecotopes listed in paragraph two, are as follows: 2,3; 3,8; 4,9; 6,8; 6,8; 6,8; 2,1; 3,0. The equivalent values, starting with a ¼-full root zone at planting, are, 1,7; 3,5; 2,4; 6,0; 4,9; 5,0; 1,1; 0,6. Although these results indicate that water content of the root zone at planting may not be important in the last three relatively high rainfall maize ecotopes, the economic importance of this factor in the case of Setlagole/Clovelly and Kroonstad/Avalon, and the two wheat ecotopes, is identified. The CPF's clearly reflect the relative production risks between the ecotopes studied. The absolute value of the CPF's need to be confirmed when the reliability of the models has been improved.

Long-term predictions of runoff and deep drainage have been computed for selected ecotopes. Deep drainage estimates have been excluded on the three ecotopes at which considerable lateral water movement occurs in the root zone, as it is considered that long-term estimates in these cases would be meaningless at this stage. The value of the long-term predictions to provide useful surface and subsurface hydrological information is doubtful at this stage because of lack of model reliability.

The potential strengths of the models have been demonstrated, as well as their amenability to improvement, and therefore the closeness of this technology to becoming a powerful practical tool for agriculture.

It is recommended that further research be undertaken, preferably by a multidisciplinary team, to provide the measurements and modelling expertise needed to rectify the model weaknesses identified. The fairly wide occurrence of considerable lateral hillside water movement which this project has exposed shows clearly that any multidisciplinary approach needs to include comprehensive hydrological studies, including catchment hydrology and groundwater recharge. The overall results of such holistic multidisciplinary studies could make a valuable contribution towards the growing need for integrated resource management.

A great deal has been learned about the functioning of the water balance processes at the ecotopes studied, about how to measure them, and the long-term influence of these processes during pedogenesis on soil physical, chemical and morphological characteristics. Expertise with regard to the latter will be a valuable aid for transferring information from ecotopes where measurements have been made, to those at which measurements have not yet been made, and so facilitate future practical applications of crop model technology for promoting improved rainfall use efficiency.

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