ICSM PROJECT FINAL REPORT

INCORPORATION OF THE CANEGRO SUGARCANE MODEL INTO THE DSSAT V4 SOFTWARE

A. Singels
with contributions from
M. Jones, C. Porter, G. Kingston, M. Smit, A. Jintrawet, S. Chinorumbe,
M. van den Berg, J. Shine and J. Jones.

December 2008

Summary

The International Consortium for Sugarcane Modelling (ICSM) was formed in 2006 to pool monetary and intellectual resources to advance sugarcane modeling. It sponsored a project to incorporate an up to date Canegro sugarcane model into the DSSAT4.5 crop model platform, which was completed successfully.

Four members sponsored the first ICSM project to incorporate an up-to-date Canegro sugarcane model into the DSSAT v4 software package. Three universities (U. Florida, U. Georgia and U. Kwazulu-Natal) collaborated. The model has been successfully incorporated into the DSSAT v4.5 modular structure. In addition to a complete restructuring of the model, numerous explicit and implicit parameter values were removed from the code, and defined as species, ecotype and cultivar parameters stored in input files available for user manipulation. Some code modifications were required to eliminate discrepancies in e.g. the calculation of evapotranspiration. Subsequent verification proved that the new DSSAT version of the model was functionally near-identical to the stand alone version. Minor remaining discrepancies could be traced back to slightly different methods of simulating non-plant processes in the stand alone and DSSAT versions. An initial model validation with data from a dryland and irrigated experiment from South Africa showed that it performed better than the DSSATv3.5 Canegro version.

An international workshop was held to train 17 prospective users of the model on its use. The model was also validated against experimental data from Australia, Thailand, Zimbabwe, USA and South Africa. It performed remarkably well for these widely differing

conditions and genotypes. The scientific documentation and a user manual have been prepared .

The model can now be linked seamlessly with cutting edge algorithms (for example for soil organic matter, soil nutrient relations and tillage impacts). Another benefit is that more scientists will now be able to contribute to the improvement of the model. This would speed up its usefulness (1) to guide and assist sugarcane agricultural research, and (2) to assist the planning and management of sugarcane production.

The model is available within the DSSAT4.5 package (http://www.icasa.net/dssat/)

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1. INTRODUCTION

The Canegro sugarcane model (Inman-Bamber (1991) was incorporated in the DSSAT (Tsuji et al, 1994) v3.1 package in 1997. Since then several research groups have made improvements and developed additional capabilities (eg Singels & Bezuidenhout, 2002) but these isolated efforts were never integrated into the latest modular version of the DSSAT version 4 (Jones et al., 2002; Hoogenboom et al., 2003). These advances are therefore inaccessible to DSSAT v4 users, while the state of the art, generic crop modelling algorithms and other utilities available in DSSAT v4, are not available to sugarcane modellers. This project attempted to address this problem.

The overall objective was to incorporate an up-to date Canegro model into the DSSAT v4 software. Specific objectives are:

- Rewriting the existing Canegro code into modules, writing new code for recently developed concepts, and linking the code with the DSSAT v4 structure.
- Verifying the correct functioning of the new code and that output similar to the stand alone Canegro code is produced.
- Validating the new DSSAT v4 Canegro model with experimental data from different countries.
- Documenting the code and concepts, as well as the validation experiments.

2. INCORPORATION OF CANEGRO INTO DSSAT

The Canegro model has been successfully incorporated into DSSAT4 as a sugarcane plant module (see Jones *et al*., 2007). Code to simulate plant processes are contained in seven sub modules within the sugarcane plant module. These are for:

- the calculation of phenological phases
- the simulation of tiller development,
- the calculation of leaf area and interception of solar radiation
- the simulation of photosynthesis and respiration
- the simulation of partitioning of biomass to root, leaf and stalk structure and to stored sucrose,
- the calculation of root length density and its distribution with depth in the soil profile,

- the calculation of radiation interception by a thermal time driven canopy (Singels & Donaldson, 2000), an option offered to the user that avoids the complex simulation of tiller cohorts and individual leaves and the need for numerous variety parameters associated with it.

Code to simulate lodging was included in the photosynthesis and canopy sub modules.

The new code was incorporated and verified in a stepwise procedure. DSSAT4-CANEGRO simulated values of tiller population, leaf area index, fractional interception of radiation, and stalk, leaf and root mass were compared with that simulated by the stand-alone model for two contrasting input scenarios (consisting of ten model runs each) and produced exactly the same values when water balance simulations were disabled (unstressed conditions).

Initial simulations with an activated DSSAT4 water balance produced results that were substantially different to the stand-alone model. This was attributed to different methods of calculating:

(1) potential evapotranspiration
(2) partitioning of potential evapotranspiration between potential transpiration and potential evaporation from the soil.
(3) actual soil evaporation
(4) runoff

These calculations all take place outside the plant module of DSSAT4.

Discrepancies in the calculation of evapotranspiration were greatly reduced when using air humidity values to calculate dew point temperature instead of estimating it from minimum temperature. Therefore, code was included in the DSSAT4 CSM to automatically calculate dew point temperature from humidity values, when this was available. Differences in potential evaporation still remain because the DSSATv4 package uses the FAO56 reference crop approach (Allen et al., 1998), while the stand-alone version uses the Penman-Monteith approach developed by McGlinchey & Inman-Bamber (1996). The calculation of potential evapotranspiration by the DSSATv4 Canegro model was calibrated to produce similar values to the stand-alone model by adjusting the value of the crop evapotranspiration coefficient in the sugarcane species file.

The discrepancy in partitioning of potential evapotranspiration was addressed by changing the calculation of evaporation from the soil in the DSSAT4 water balance module, making it a function of total leaf area (i.e. green leaves plus dead leaves), as is done in the standalone model.

These changes resulted in a reduction of the discrepancies between the two models to levels that were deemed acceptable. The remaining minor discrepancies could all be explained by different methods of simulating non-plant processes. A full statistical verification with ten hypothetical water stressed and ten hypothetical well-watered scenarios demonstrated that the two model versions were in effect functionally equal.

The Canesim canopy and lodging algorithms were included as options and these have been verified as working correctly. The coupling of the mass balance with root, leaf and tiller development was considered too complex and time consuming to be done in this project, as it will require major changes that could have profound impacts on model performance. With regard to management of irrigation and crop cycling, it was decided that the existing DSSAT4 options provide adequate functionality for sugarcane simulation.

Genetic parameters

All explicit and implicit parameter values were removed from the stand-alone code and redefined as species, ecotype or cultivar parameters, following the DSSAT framework. The approach was to rather make more than fewer parameters available for adjustment by the end user and therefore the ecotype and cultivar files contain large numbers of parameters, compared to other crops. It is envisaged that there will be consolidation and simplification of parameters in future, as new knowledge is gained on the impacts of parameters on crop growth and development.

Cultivar parameters (20) mainly relate to biomass partitioning (5), canopy development (6 leaf and 4 tiller parameters), phenological phasing (4) and lodging susceptibility (1), and these are expected to vary between cultivars. Ecotype parameters (32) are expected to vary less with cultivars and are also more difficult to adjust because data would not be readily available. Parameters for different tillering types are contained here. Species parameters (24) relate to photosynthesis, respiration, biomass partitioning, root growth, plant response to water stress and lodging.

Details about genetic parameters are provided in chapter 3 of the scientific documentation.

3. MODEL VALIDATION

The new Canegro DSSAT 4.5 was initially validated with data from one irrigated and one dryland experiment. The dryland experiment was conducted at La Mercy, South Africa (described by Inman-Bamber, 1994 and Inman-Bamber, 1994b) and the irrigated experiment conducted in Pongola, South Africa (described by Rostron, 1972 and Inman-Bamber, 1994b). Results are described in detail in chapter 4 of the model documentation (Appendix I). Validation results for stalk dry mass are shown in Fig 1 and 2. There is good agreement between simulated and observed values of stalk dry mass although there seems to be a tendency to underestimate high values. The root mean square error and R^2 values were 6.88 t/ha and 0.72 respectively for the La Mercy experiment, and 5.17 t/ha and 0.78 respectively for the Pongola experiment. This is regarded as acceptable.

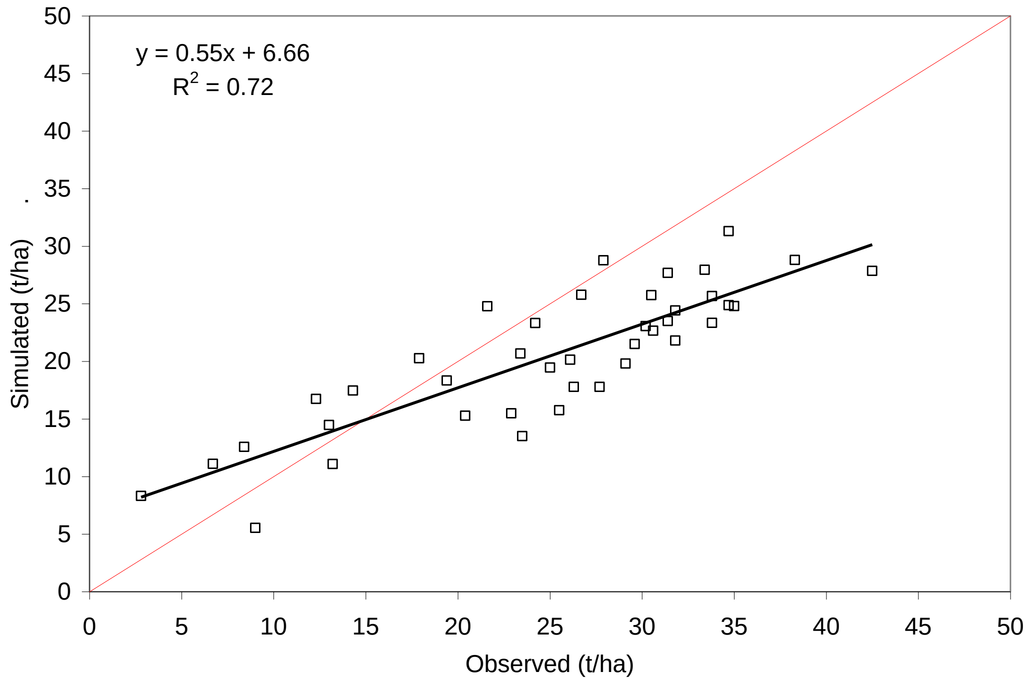

Fig 1. Simulated and observed stalk dry mass for the La Mercy experiment

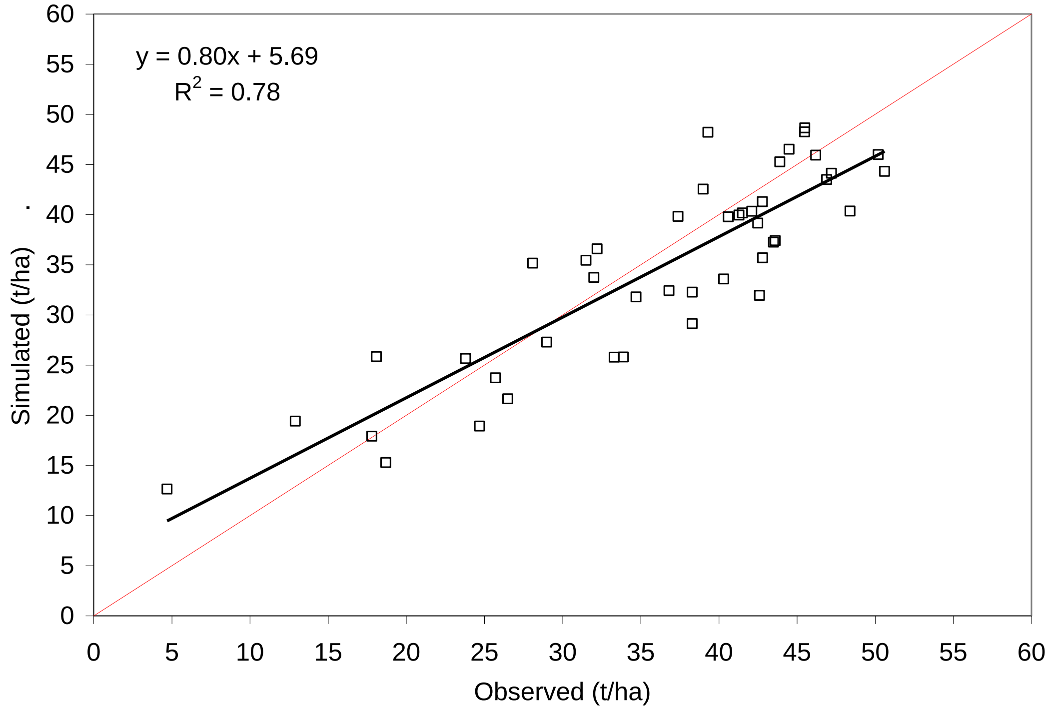

Fig 2. Simulated and observed stalk dry mass for the Pongola experiment.

The model was then subjected to a more comprehensive validation using data from across the world. This was done during a validation workshop held from 6 to 9 August 2007 at SASRI, Mount Edgecombe that was attended by 17 delegates from SASRI (South Africa), BSES (Australia), CSIRO (Australia), Chiang Mai University (Thailand), SCGC (Florida), ZSAES (Zimbabwe), SRC (Fiji), CIRAD (France), University of Florida, KESREF (Kenya) and Agriculture Canada. Prof Jim Jones and Dr. Cheryl Porter assisted SASRI staff in leading the workshop and tutoring delegates (see Fig. 3). The full report on the validation workshop is given in Appendix III

Fig. 3. Validation workshop delegates

The first two days consisted of hands-on training on installing and running the new DSSAT4.5 Canegro model. Delegates received comprehensive model documentation and a licensed copy of the software and were able to set up, execute and interpret simulation runs.

The last two days were spent on calibrating the model (adjusting cultivar parameters) using actual observations from field experiments from Australia, Thailand, Zimbabwe, Florida and South Africa. The model performed remarkably well for these widely different locations, even before any adjustment to cultivar parameters. The model underestimated rate of growth in winter for two independent scenarios and this suggests the existence of a model shortcoming that needs investigation. Of the original list of 54 cultivar parameters, seventeen key parameters were identified that described major cultivar differences in the processes of phenological development, canopy development, biomass accumulation and partitioning. The workshop succeeded in testing and expanding the database of cultivar parameters from Nco376 to include two ZN, two Q and four other N cultivars. Valuable comments were obtained from delegates to improve the DSSATv4.5 shell and the Canegro model.

4. MODEL DOCUMENTATION

Model concepts and equations and the initial validation of the DSSAT Canegro v4.5 model have been described by Singels, Jones and van den Berg (2008) and is included in Appendix I. The document describes the simulation of phenological development, canopy formation, biomass accumulation and partitioning and the impact of climate, water stress and lodging on these processes.

A user manual has also been compiled (Jones and Singels, 2008, see Appendix II). This document guides the user to set up and execute a Canegro simulation run within the DSSAT enviroment, manipulate weather soil and management input data, calibrate plant input parameters, and compare simulated output data with observed data. It takes the form of a tutorial, where a complete simulation is set up from scratch. Each step in this process is described. Whereas much of this process is applicable to all DSSAT models, emphasis is placed on sugarcane-specific aspects.

Every DSSAT simulation is defined in an Experiment file (FileX), which references soil (FileS) and weather (FileW) files. The user manual describes how to go about creating a FileX for running sugarcane simulations, as well as providing some information on creating weather and soil files, particularly where these have special relevance for sugarcane.

The Canegro model in DSSAT makes use of genetic information defined in species, ecotype and cultivar files. Some guidance for creating new cultivar and ecotype definitions is also presented in the user manual.

5. BUDGET

Project expenditure is summarized in Table 1. Funds were expended according to the planned budget. Funds were administered by SASRI and a financial audit indicated acceptable administration and application of funds.

Table 1. Project budget (US$).

	Income	Expenditure
Income from sponsors	25900	
Programmer training		5 000
Programmer travel/acc		7 000
Consultation – programming		5 500
Validation workshop		
Travel/acc for tutors		7 000
Meals, printing etc.		1 000
Documentation		400

6. CONCLUSIONS

An up to date version of the Canegro model has been successfully incorporated into the DSSAT v4.5 modular structure. In the process, numerous explicit and implicit parameter values were removed from the code, redefined as species, ecotype and cultivar parameters and stored in input files available for user manipulation. Some code modifications were required to eliminate discrepancies in e.g. the calculation of evapotranspiration. A subsequent verification procedure proved that the new DSSAT version of the model was functionally near-identical to the stand alone version. Minor remaining discrepancies could all be traced back to slightly different methods of simulating non-plant processes in the stand alone and DSSAT versions. An initial model validation with data from a dryland and irrigated experiment from South Africa showed that it performed better than the DSSATv3.5 Canegro version.

An international workshop was held to train 17 prospective users of the model on its use. The model was also validated against experimental data from Australia, Thailand, Zimbabwe, USA and South Africa. It performed remarkably well to simulate biomass, cane and sucrose yield for these widely differing conditions and genotypes. The scientific documentation and a user manual have been prepared.

The model can now be linked seamlessly with cutting edge algorithms (for example for soil organic matter, soil nutrient dynamics and tillage impacts). Another benefit is that more scientists will now be able to contribute to further improvement of the model. This would speed up its usefulness (1) to guide and assist sugarcane agricultural research, and (2) to assist the planning and management of sugarcane production.

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7. ACKNOWLEDGEMENTS

We gratefully acknowledge:

- the financial and in kind contributions from the ICSM, BSES, SCGC, ZSAES, SASRI, Chiang Mai University, University of Florida and University of Georgia,
- the vision and initiative of Rasack Nayamuth of MSIRI that provided the impetus to get the project going, and
- the support from Gerrit Hoogenboom and other DSSAT colleagues.

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APPENDICES

I - Model documentation

See attached document

II - User documentation

See attached document

III - Validation workshop report

See attached document