THE DSSAT4.5 CANEGRO MODEL: A USEFUL DECISION SUPPORT TOOL FOR RESEARCH AND MANAGEMENT OF SUGARCANE PRODUCTION

By

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KEYWORDS: Crop Model, Biomass, Sucrose Mass, Leaf Area Index, Simulation.

Abstract

THE NEW DSSATv4.5 Canegro model allows users to combine the latest advances in sugarcane modelling with the latest DSSAT functionality to address production and research problems. The objectives of this poster are to (1) describe the main features of the model, (2) report on its accuracy of simulating biomass, cane and sucrose yields in different parts of world, and (3) highlight potential applications in sugarcane research and management. The model uses daily weather data to simulate canopy development, interception of radiation, biomass accumulation and partitioning. It simulates the effect of water stress and lodging on photosynthesis, growth and sucrose storage. Eighteen cultivar parameters are used to simulate genetic control of crop response to environmental factors. Simulated green leaf area index, aboveground biomass, stalk mass and sucrose mass were compared with observed data from Australia, Brazil, South Africa, Thailand and Zimbabwe. The model performed remarkably well for these widely different cropping situations and cultivar types. In some cases, the simulated biomass accumulation rates declined too rapidly in winter leading to an underestimation of yields. This needs further investigation. The DSSATv4.5 Canegro model is now easily accessible and may be applied, after thorough testing, to support research and management world-wide.

Introduction

The new DSSAT v4.5 Canegro model allows users to combine the latest advances in sugarcane modelling with the latest DSSAT (Jones *et al.*, 2003) functionality to address production and research problems.

The objectives of this poster are to (1) describe the main features of the model, (2) report on its accuracy of simulating biomass, cane and sucrose yields in different parts of world, and (3) highlight potential applications in sugarcane research and management.

Model description

The DSSAT v4.5 Canegro plant module (Singels *et al.*, 2008) uses soil properties, weather data, management inputs and genetic parameters to simulate the daily growth and development of sugarcane crops.

The duration of phenological phases (germination, tiller production, tiller senescence and stalk elongation) are simulated using the thermal time (TT) concept.

Tiller population and numbers of green and dead leaves on the primary tiller are calculated using TT. The product of leaf size, tiller population and leaf number provides total and green leaf area index (GLAI).

Interception of photosynthetically active radiation is calculated using Beer's law. Biomass accumulation is calculated following the radiation use efficiency approach but also accounting for respiration.

Partitioning of biomass to different plant components, including stalk sucrose, is calculated using a source-sink approach and accounts for physiological age, temperature and water stress.

Water stress is calculated following the CERES approach (Jones and Kiniry, 1986) of process-specific soil water deficit factors.

Water stress affects rates of transpiration, photosynthesis, growth and sucrose storage. The model uses 18 cultivar parameters to simulate genetic control of crop growth and development to environmental factors.

Model testing

The model was tested using experimental data from Australia, Brazil, South Africa, Thailand and Zimbabwe (see Table 1).

The model was calibrated for cultivars other than NCo376 by adjusting the values of some cultivar parameters so that simulations of phenological, tiller and leaf development and of biomass partitioning followed observations closer.

Simulation accuracy was quantified using the root mean square of the deviations between simulated and observed values, expressed as a percentage of the mean observed value (RMSE).

Visual comparisons of simulations with experimental data showed that the model performed remarkably well for most of these widely different cropping situations and cultivar types.

RMSEs for GLAI, biomass, stalk dry mass and sucrose mass ranged from 11 to 45, 14 to 26, 13 to 34 and 7 to 34% respectively (see Table 1).

The large errors are ascribed to incomplete cultivar calibration or to apparent model shortcomings.

The study highlighted areas that may require refinement:

- The simulation of tiller appearance and senescence does not adequately account for the dynamic effects of planting density and radiation transmission through the canopy. This leads to inaccurate predictions of GLAI at times.
- Observations from several data sets (South Africa, Australia, Brazil) suggest that the simulated reduction in the rate of biomass accumulation due to decreased temperature is too drastic. Further investigation into this aspect is required.

Model applications

Sugarcane crop models have many applications in research and management of sugarcane production. These include:

1. climate change impact studies (Marin *et al*. 2009);
2. exploring ideotypes for given environments;
3. forecasting crop yield and quality (Bezuidenhout and Singels, 2007); and
4. supporting irrigation management (Singels and Smith, 2006).

The inclusion of an up-to-date Canegro model into the DSSATv4.5 package makes sugarcane modelling more easily accessible and should enhance sugarcane research and management. However, local testing is necessary before the model can be applied with confidence.

Table 1—Experimental details and simulation accuracy based on root mean square error (RMSE).

Site	Soil depth, texture class	Dryland/ Irrigated	Cultivars	Start date (month, year)	RMSE GLAI	RMSE Biomass	RMSE Stalk mass	RMSE Sucrose mass	Source of data
La Mercy, South Arica, 29°34'S, 30°8'E	1.65m, sandy clay loam	Dryland	NCo376	Jun89, Aug89, Oct89, Dec89, Feb90, Apr90, Jun90, Aug90	26.5	14.6	27.5	31.2	Inman-Bamber, 1994
Pongola, South Africa, 27°24'S, 31°35'E	4m sandy clay loam	Irrigated	NCo376	Dec68, Feb69, Apr69, Jun69, Jul69, Sep69, Nov69, Jan70	NA	NA	14.4	19.7	Rostron, 1972
Mount Edgecombe, South Africa, 29°42'S, 31°2'E	0.6m sandy clay loam	Irrigated	NCo376, N31, N37	Oct03, Apr04	45.4	26.0	33.6	34.0	Singels and Smit (2008)
Bruynshill, South Africa, 29°25'S, 30°30'E	2m sandy clay loam	Irrigated	NCo376, N31, N37	Oct03, Apr04	30.1	15.2	13.2	20.3	Singels and Smit (2008)
Bundaberg Australia,25°30'S, 152°14'E, 27m	3m, clay loam	Irrigated	Q138, Q141	Aug91, Aug92	24.2	18.6	17.2	32.0	Pers. comm., Liu and Kingston
Chiredzi, Zimbabwe, 21°01'S, 28°38'E	1 m sandy loam	Irrigated	NCo376, N14, ZN7, ZN6	Oct01	25.9	NA	NA	7.5	Zhou, 2003
Chiang Mai, Thailand, 18° 45'N, 98° 55'E	1.15m sandy clay loam	Irrigated	K84-200, U-Thong2	Feb95	11.4	26.4	34.2	31.3	Jintrawet *et al.*, 1997
Piracicaba, Brazil, 22°53´S, 47°30´W	3.5m clay loam	Dryland, irrigated	NCo376, R570, SP83-2847 RB72454	Oct04	20.8	19.8	29.8	NA	Suguitani, 2006

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LE MODEL DSSAT4.5 CANEGRO: UN OUTIL D'AIDE A LA DECISION UTILE POUR LA RECHERCHE ET LA GESTION DE LA PRODUCTION DE CANNE A SUCRE

Par

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MOTS CLÉS: Modèle de Croissance, Biomasse, Masse de Saccharose, Indice Foliaire, Simulation.

Résumé

LE NOUVEAU modèle Canegro DSSATv4.5 permet aux utilisateurs de combiner les dernières avancées en modélisation de la canne à sucre avec les toutes dernières fonctionnalités de la plateforme DSSAT pour résoudre des problèmes de recherche et de production. Les objectifs de ce poster sont (1) de décrire les caractéristiques principales du modèle, (2) de montrer sa capacité à simuler la biomasse, et les rendements en canne et en sucre dans différentes parties du monde, et (3) d'exposer les applications potentielles en gestion et recherche sur la canne à sucre. Le modèle utilise des données climatiques journalières pour simuler le développement du couvert, l'interception du rayonnement, l'accumulation de biomasse et sa partition. Il simule l'effet du stress hydrique et de la verse sur la photosynthèse, la croissance et le stockage du saccharose. 18 paramètres variétaux sont utilisés pour simuler le contrôle génétique de la réponse des plantes aux facteurs environnementaux. Les indices foliaires, biomasse aérienne, masse de tige et de saccharose simulés furent comparés à des résultats observés en Australie, au Brésil, en Afrique du Sud, en Thailande et au Zimbabwe. Le modèle se comporta de façon remarquable pour ces types de variétés et de situations très différentes. Dans certains cas, les taux d'accumulation simulés de biomasse déclinèrent trop rapidement en hiver, entraînant une sous estimation des rendements. Ces différences nécessitent des recherches plus poussées. Le modèle Canegro DSSATv4.5 est maintenant facilement accessible, et peut être appliqué, après un test approfondi, pour aider la recherche et la gestion à l'échelle mondiale.

EL MODELO CANEGRO DSSAT4.5: UNA HERRAMIENTA UTIL EN LA TOMA DE DECISIONES EN INVESTIGACION Y GESTION DE LA PRODUCCION DE CANA DE AZUCAR

Por

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PALABRAS CLAVE: Modelo de Cultivo, Biomasa, Producción de Sacarosa, Índice de Área Foliar, Simulación.

Resumen

EL NUEVO modelo Canegro DSSATv4.5 permite a los usuarios combinar los últimos avances en modelación de caña de azúcar con la funcionalidad de DSSAT para abordar problemas en investigación y producción. Los objetivos del presente poster son (1) describir las funciones principales del modelo, (2) reportar su precisión para simular rendimientos de biomasa, caña y azúcar en diversas partes del mundo y (3) resaltar aplicaciones potenciales en gestión e investigación en caña de azúcar. El modelo utiliza datos diarios de clima para simular el desarrollo del follaje, la intercepción de la radiación, así como la acumulación y partición de biomasa. Además simula el efecto del estrés hídrico y acame en la fotosíntesis, crecimiento y almacenamiento de azúcar. Se utilizaron 18 parámetros del cultivar para simular el control genético de la respuesta de la planta a los factores ambientales. Se comparo el índice de área foliar, biomasa aérea, cantidad de tallos y sacarosa con datos de Australia, Brasil, Sudáfrica, Tailandia y Zimbabue. El modelo funciono notablemente bien para estas diversas condiciones de cultivo y tipos de cultivares. En algunos casos, los índices de acumulación de biomasa decrecieron muy rápidamente en invierno, lo cual causo una subestimación de los rendimientos. Es necesario continuar la investigación en ese aspecto. Actualmente el modelo Canegro DSSATv4.5 es fácilmente accesible y, luego de cuidadosas pruebas, puede aplicarse a nivel mundial para apoyar la investigación y gestión.