ESTIMATING SUGARCANE YIELDS WITH OY-THAI INTERFACE

By

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Abstract

The large-scale estimation of sugarcane yields is undertaken by various agencies in Thailand. The current method depends on personal experiences and site visits for cross checking. Advances in information technologies, both software and hardware, has created opportunities to improve estimation methods. The OyThai 1.0 interface was evaluated as a link between a DSSAT v 3.5 compatible sugarcane model and an ArcView Windows-based GIS package for use in simulating yields at the farm or regional level. With this system, users must provide spatial data of the area in cane and soil series, weather, and administrative boundary maps and soil profile. The system can be used to estimate yields and economic variables associated with different management practices. Simulation results can be analysed using tabular statistics and thematic maps. The linking, with necessary spatial and attribute databases, has been completed for five key cane-producing provinces covering 1600 km² in Thailand.

Methods

Total cane production for any land area in a given production system may be estimated as a product of cane area harvested and average cane yield. Information on harvested sugarcane areas may be derived through grower interviews, field surveys, and satellite image interpretations. Similarly, average sugarcane yields for a district or province can be derived by interviewing the growers in the region, by collecting crop yield data, or by using a validated sugarcane model to estimate sugarcane yields. The objectives of this research were to develop and test a model for predicting sugarcane yields, develop a spatial database, and develop a human-machine interface.

To accomplish the first task, the team focused on testing and using a sugarcane model (CANEGR0-DSSAT) (Hoogenboom et al., 1999) to estimate cane yields for various soil types, management practices, and weather conditions. The second task was devoted to spatial database development, including administrative (district) boundaries, weather and climate zone maps, soil series maps, and sugarcane plot maps. We adopted the digital national administrative boundary map for this purpose. We also developed a satellite image analysis method, which allows users to produce digital information of areas planted and harvested in five provinces in the Northeast region of Thailand. Several interface shells were developed to link between the simulation model and various spatial databases.

A field experiment was designed to generate the DSSAT's minimum data set for use in the CANEGR0-DSSAT model validation process. The experiment was conducted at three locations in Thailand, namely, Suphanburi (14°N), Khon Kaen (16°N), and Chiang Mai (18°N). Treatments were arranged in a split-plot design, with three replications. Two planting dates were the main plots and two sugarcane varieties were the sub-plots.
The experiments were initiated with the planting of cane in February 1994 and were terminated in December 1998. Plant samples were taken from each plot at monthly intervals, between July and November each year, to determine weights of different cane plant parts, i.e., leaf blade, leaf sheath, and stem as well as sugar yield components. The soil was classified as a Typic Haplustalfs at Suphanburi and as an Oxic Paleustults at Khon Kaen and Chiang Mai. Soil samples were taken at different depths before planting and analysed for nitrate and ammonium nitrogen concentrations and initial soil moisture and soil pH levels.

A weather station was installed at each site to monitor the daily changes of total solar radiation, air temperature, and rainfall. Data were then entered into a computer using the DSSAT 3.5 format.

Two major sugarcane plantation areas were selected, one each from Khon Kaen and Suphanburi provinces. The Khon Kaen cane area can be characterised as a mosaic of small holders scattered on an undulating topography. The Suphanburi cane production area can be characterised as continuous sugarcane fields belonging to large holders. In each province, LANDSAT 5 TM images were obtained on November 3, 1994, and April 22, 1995. These were the only days when 90% of the areas were cloud-free. Image rectification was used to improve map coordinate alignment with the digital images.

ERDAS software and a computer with a UNIX operating system were used to classify the images. Both supervised and unsupervised classification methods (Lillesand and Kieffer, 1994) were used and evaluated based on a classification accuracy assessment parameter, i.e., error matrix and KHAT statistic (Congalton, 1991). Two digital maps of sugarcane fields were produced from the November 1994 and April 1995 images. A similar image classification process was used in five provinces in Northeast Thailand.

Various computer interfaces were evaluated under both DOS and Windows environments to assist in linking the spatial databases to the CANEGRO-DSSAT sugarcane model (Lal et al., 1992; Hartkamp et al., 1999). Of the interfaces evaluated, the OyThai 1.0 interface appeared to have the greatest applicability. The OyThai 1.0 is a Windows-based interface, with similar concepts and principles as the AEGIS/Win (Engel et al., 1997), which allows users to place boundaries on the size of the area to be used to estimate sugarcane production, define management practices to be used in the selected area, simulate sugarcane production in the selected area, and to display the simulated sugarcane production estimates of the selected area. Operation of the OyThai 1.0 software requires a personal computer with a Windows 95, 98, or 2000 operating system and at least 3-MB of free hard disk space and the DSSAT 3.5 or higher program (Figure 1).

The core databases of the OyThai 1.0 system includes a soil series map at the 1:50 000 scale digitised, with associated DLDSIS (Vearasilp and Songsawat, 1991) soil attribute data sets, maps of administrative boundaries, weather station coverage, and sugarcane areas for the same region. These data and models are manipulated spatially on an IBM PC computer running a Windows operating system.

The developed OyThai interface system can run an unlimited number of sugarcane management simulations based on the selections by the user or the

![Fig. 1—File structure for the Oy-Thai 1.0 Interface.](image)
grower. Our example in this paper deals with a sugar-
cane crop that was simulated, using historical
weather data. The cultivar selected was ‘U-thong2’,
planted on February 1, at a planting density of
1.5 plants/m2 to rows spaced 1.5 m apart. To study
the effect of water management on yield, both a
rainfed crop and an irrigated crop were simulated.

For the irrigated management strategy, an auto-
matic irrigation routine was used, in which the crop
was irrigated when the soil water content in the top
0.30 m of the profile dropped below 70% of the plant
extractable soil water content. It was also assumed
that nitrogen or any other plant nutrients were
non-
limited and that the plants were not under stress from
other pests, diseases, or weeds. It was also assumed
that each Simulation Mapping Unit (SMU), corre-
sponding to a particular soil type and weather code
was identical within the SMU.

Results and discussion

The climate in these areas ranged, temporally and
spatially, from humid to semi-arid tropical. The
Chaiyaphum region with mean annual precipitation
of 1068 mm is characterised as the rain-shadow zone,
Udon thani as the humid region with mean annual
precipitation of 1364 mm, and the Khon Kaen area as
the semi-arid tropics with a mean annual precipitation
of 1185 mm. Table 1 shows monthly averages of
total precipitation, daily maximum and minimum air
temperature, and daily solar radiation for all three
weather stations.

Table 1—Averaged monthly weather data of the three weather zones in Northeast Thailand.

<table>
<thead>
<tr>
<th>Month</th>
<th>Radiation MJ/m²/d</th>
<th>T_max (°C)</th>
<th>T_min (°C)</th>
<th>Rainfall (mm)</th>
<th>Rainy days (days/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CY</td>
<td>KK</td>
<td>UT</td>
<td>CY</td>
<td>KK</td>
<td>UT</td>
</tr>
<tr>
<td>Jan</td>
<td>14.5</td>
<td>16.0</td>
<td>14.7</td>
<td>31.0</td>
<td>30.6</td>
</tr>
<tr>
<td>Feb</td>
<td>14.7</td>
<td>16.4</td>
<td>16.4</td>
<td>33.0</td>
<td>33.0</td>
</tr>
<tr>
<td>Mar</td>
<td>14.9</td>
<td>16.0</td>
<td>14.9</td>
<td>35.6</td>
<td>35.2</td>
</tr>
<tr>
<td>Apr</td>
<td>14.7</td>
<td>16.4</td>
<td>14.6</td>
<td>36.1</td>
<td>35.9</td>
</tr>
<tr>
<td>May</td>
<td>21.4</td>
<td>15.9</td>
<td>21.0</td>
<td>34.8</td>
<td>34.7</td>
</tr>
<tr>
<td>June</td>
<td>20.7</td>
<td>14.5</td>
<td>19.9</td>
<td>33.4</td>
<td>33.5</td>
</tr>
<tr>
<td>July</td>
<td>20.5</td>
<td>14.3</td>
<td>19.3</td>
<td>32.9</td>
<td>32.8</td>
</tr>
<tr>
<td>Aug</td>
<td>19.9</td>
<td>13.6</td>
<td>32.4</td>
<td>32.1</td>
<td>31.6</td>
</tr>
<tr>
<td>Sep</td>
<td>19.3</td>
<td>13.8</td>
<td>18.6</td>
<td>32.0</td>
<td>31.7</td>
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<tr>
<td>Oct</td>
<td>11.4</td>
<td>15.0</td>
<td>11.6</td>
<td>31.3</td>
<td>31.4</td>
</tr>
<tr>
<td>Nov</td>
<td>12.3</td>
<td>15.5</td>
<td>13.1</td>
<td>30.8</td>
<td>30.8</td>
</tr>
<tr>
<td>Dec</td>
<td>13.7</td>
<td>15.4</td>
<td>14.3</td>
<td>29.6</td>
<td>28.8</td>
</tr>
</tbody>
</table>

Note: CY = Chaiyaphum, KK = Khon Kaen, UT = Udon thani

Table 2—Comparison of the estimated and surveyed
sugarcane planted area (ha) in five provinces.

<table>
<thead>
<tr>
<th>Province</th>
<th>LANDSAT 5 estimated</th>
<th>OAE survey</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Khon Kaen</td>
<td>56 200</td>
<td>51 600</td>
<td>-8.8</td>
</tr>
<tr>
<td>Udon</td>
<td>83 200</td>
<td>77 800</td>
<td>-6.9</td>
</tr>
<tr>
<td>Nongbualum Pool</td>
<td>3 300</td>
<td>4 000</td>
<td>-17.6</td>
</tr>
<tr>
<td>Loei</td>
<td>20 200</td>
<td>15 400</td>
<td>-31.4</td>
</tr>
<tr>
<td>Chaiyaphum</td>
<td>32 600</td>
<td>67 700</td>
<td>-51.9</td>
</tr>
<tr>
<td>Total</td>
<td>195 500</td>
<td>216 500</td>
<td>-9.7</td>
</tr>
</tbody>
</table>

Note: OAE = Office of Agricultural Economics, Ministry of Agri.
& Coop., Thailand. Overall Bias = -4200 ha and Root Mean Square Error (RMSE) = 9 400 000 ha.

Soil and climatic diversity within the areas make
them good candidates for this study. Their perform-
ance would be indicative of several other locations in
Thailand and other sugarcane-growing regions. Soil
texture (sand, silt, clay content), bulk density and
initial soil moisture content exhibited moderate to
high variability across the province, but only modest
changes with depth. The high lateral variability in soil
texture is also reflected in the surface texture map for
the watershed, which shows a wide range in soil types
(sand to silty clay), as well as very complex spatial
distributions. The organic carbon (OC) and initial soil
moisture (ISM) content values are moderately to
extremely variable across the province for OC and for
ISM at any particular depth, and also decreased sub-
stantially in mean value with increasing depth.

Simulated sugarcane dry weight for the rainfed
area with additional fertiliser varied between 11.7
and 18.8 t/ha (Table 3). The lowest yield was found
on SMU#9 (the Chiang Rai soil series), which has a
relatively low water holding capacity. The highest
yields were found on SMU#2 (the Korat soil series).
Mean difference between simulated and observed

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sugarcane yields of 12 SMUs is only 4.9 percent. This compares favourably with the historical reports of variation of sugarcane yields in Thailand by several agencies, both private and public. The small difference in observed and simulated yield demonstrates the ability of the model to predict leaf appearance rates, growth and phenology processes of the U-thong 2 sugarcane cultivar. Furthermore, the soil water balance sub-module with the model accurately predicted the soil water dynamics of the wrapped conditions of the 12 SMU units.

One would also want to use the model to exercise production options, i.e., would irrigation help improve sugarcane yields? When irrigation was included to create a non-stressed soil environment, simulated sugarcane dry weight increased significantly and reached a level between 24.5 and 53.5 t/ha, independent of the spatial variation of the soil water holding characteristics (Table 3). The difference between simulated and observed sugarcane yields for the 12 SMUs was 109.3 percent. Evidently, the spatially and/or temporally distributed weather and soil attributes interact in such a way as to enhance the spatial variability, but eliminate the annual variability, of sugarcane yield. However, there are many technical and practical reasons why simulated sugarcane yields may not be similar to measured yields, including inadequate and inappropriate model algorithms, incorrect model inputs, inadequate model calibration and large experimental error.

These results encourage us to continue work on the simulation of complex sugarcane cropping systems. In addition, we will continue to improve the model's capacity in simulating the effects of pests on yield, which will allow to users to improve model accuracy on a large scale simulation. Research to improve simulation of these processes is in progress and need close collaboration between researchers and sugarcane growers. We also will continue to improve the linkage between the model and user's interface in the Thai language. The Thai language interface is very important since more growers can be trained to use the model and the interface, and more tests on the model can be carried out by the growers and grower associates.

**Conclusion**

Although more testing is required, especially under irrigated conditions, we have demonstrated technology that makes it possible to estimate yields of sugarcane on a field or provincial scale with accuracy of the order of 4.8%. The technology can be adapted for any crop. OyThai 1.0 interface allows users to link the CANEGRO-DSSAT sugarcane model with spatial databases under a Windows's PC environment. Spatial data requirements are: administrative (boundaries at the district and sub-district level), soil series, weather, sugarcane management practices, and sugarcane area maps. A fully developed spatial database (with known georeferenced coordinates) and this relatively simple interface, together with a process-oriented crop growth model, was able to produce reasonable simulations of biomass production and sugar yield.

Additional research is needed in using the programming language within the GIS package, which may result in greater flexibility in coordinating data input, model execution, and output of results. This strategy could provide a means for developing useful analytical tools for resource managers.

**Acknowledgments**

The research team thanks the Thailand Research Fund (TRF) for financial support during July 1994–October 2001. We thank the cane growers in Nong Thong sub-district in Khon Kaen province for their cooperation during the course of our study. The authors would like to express sincere thanks to the three research teams carrying out the 1995 to 1998 validation experiments, namely; Chiang Mai University, Khon Kaen University, and Suphanburi Field Crop Research Center. Finally, we thank Mrs Taseena Sonsayawichai for sharing the observed sugarcane data for the 12 SMUs.

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**Table 3—Comparison between estimated and observed cane dried stalk yield based on 12 Simulation Mapping Units (SMUs) with different soil series and weather zones in three provinces.**

<table>
<thead>
<tr>
<th>SMU #</th>
<th>Soil series name</th>
<th>Weather zone</th>
<th>Simulated</th>
<th>Observed</th>
<th>Percent different from observed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rainfed</td>
<td>Irrigated</td>
<td>Rainfed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>t/ha</td>
<td>t/ha</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Korat</td>
<td>05</td>
<td>14.2</td>
<td>30.4</td>
<td>12.9</td>
</tr>
<tr>
<td>2</td>
<td>Korat/Phon Phisai</td>
<td>05</td>
<td>15.6</td>
<td>24.2</td>
<td>12.8</td>
</tr>
<tr>
<td>3</td>
<td>Korat</td>
<td>06</td>
<td>18.8</td>
<td>30.8</td>
<td>13.9</td>
</tr>
<tr>
<td>4</td>
<td>Roi Et Loamy</td>
<td>08</td>
<td>15.8</td>
<td>35.3</td>
<td>11.9</td>
</tr>
<tr>
<td>5</td>
<td>Korat</td>
<td>08</td>
<td>14.8</td>
<td>30.8</td>
<td>13.9</td>
</tr>
<tr>
<td>6</td>
<td>Phon Phisai</td>
<td>08</td>
<td>15.6</td>
<td>25.2</td>
<td>13.1</td>
</tr>
<tr>
<td>7</td>
<td>Korat/Phon Phisai</td>
<td>08</td>
<td>15.6</td>
<td>24.1</td>
<td>13.9</td>
</tr>
<tr>
<td>8</td>
<td>Phon Phisai</td>
<td>04</td>
<td>15.6</td>
<td>24.6</td>
<td>16.4</td>
</tr>
<tr>
<td>9</td>
<td>Chiang Rai</td>
<td>04</td>
<td>11.7</td>
<td>24.5</td>
<td>13.2</td>
</tr>
<tr>
<td>10</td>
<td>Wang Hai</td>
<td>04</td>
<td>15.6</td>
<td>53.5</td>
<td>17.9</td>
</tr>
<tr>
<td>11</td>
<td>Rakhaburi</td>
<td>04</td>
<td>15.6</td>
<td>32.1</td>
<td>18.6</td>
</tr>
<tr>
<td>12</td>
<td>Chutturat</td>
<td>04</td>
<td>15.6</td>
<td>33.1</td>
<td>17.6</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td>15.4</td>
<td>30.7</td>
<td>14.7</td>
</tr>
</tbody>
</table>

Overall bias = –2.1 t/ha and root mean square error (RMSE) = 5.8 t/ha
REFERENCES


ESTIMATIONS DES RENDEMENTS DE LA CANNE A SUCRE A L’AIDE DE L’INTERFACE OY-THAI

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Résumé

L’estimation des rendements de la canne à sucre plantée sur des grandes superficies est une activité importante pour de nombreuses agences en Thaïlande. La méthode couramment utilisée est basée sur les expériences personnelles, mais ne pouvant être facilement vérifiée, elle est souvent mise en cause. Grâce aux progrès accomplis dans le domaine de l’informatique, les méthodes d’estimation ont pu être améliorées. Oythai 1.0 est un logiciel convivial permettant la visualisation des résultats des simulations tant au niveau d’une ferme qu’aux niveaux de régions. Il fut développé pour relier un modèle de canne à sucre, qui est compatible à DSSAT v 3.5, et à ARCVIEW, un logiciel SIG. Les données spatiales telles que la superficie sous culture, la carte pédocologique, la carte climatique ainsi que les limites administratives, devraient être fournies par l’utilisateur. Les données descriptives concernant le profil du sol et les variations climatiques journalières sont aussi requises. L’interface permet d’estimer les rendements en canne tout en tenant compte des variables économiques de ces régions aussi bien que la gestion des pratiques culturales telles que la variété de la canne, la date de plantation et le programme d’irrigation. Les résultats des simulations peuvent être présentés sous forme de tableaux et de cartes thématiques pour des besoins d’analyses. Une analyse spatiale utilisant le lien établi entre cartes et bases de données descriptives a été faite sur une superficie de 160 000 km carrés, regroupant les cinq provinces clés de la production de la canne à sucre en Thaïlande: Loei, Nongbualumpoo. Udonthanee, Chaiyaphum et Khon Kaen.

Mots clés: CANEGRO-DSSAT, interface utilisateur-machine, gestion de ressource, cartographie de rendement.

ESTIMACIÓN DE LA PRODUCCIÓN DE CAÑA CON LA INTERFASE OY-THAI

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Resumen

La estimación la producción en las grandes plantaciones de caña es un servicio prestado por varias entidades en Tailandia. El método actualmente en uso depende de la experiencia personal y de visitas al campo para verificar la información. Los avances en los sistemas de información, de programas y de computadoras, han creado oportunidades para mejorar los métodos de estimación. La interfase OY-Thai 1.0 fue evaluada en conjunto con el modelo 3.5 de DSSAT para caña de azúcar, como también con el sistema de información geográfica ArcView que se usó para simular la
producción a nivel de finca y regional. Con este sistema, los usuarios deben proporcionar información espacial de las plantaciones, series de suelos, clima, y los mapas con las fronteras administrativas y el perfil del suelo. El sistema puede ser usado para estimar la producción y las variables económicas asociadas con las diferentes prácticas de manejo. Los resultados de las simulaciones pueden ser analizados usando estadística tabular y de mapas temáticos. La unión necesaria entre los datos espaciales y los atributos de las bases de datos, ha sido compilada para cinco provincias productoras de caña que cubre un área de 1600 km² en Thailandia.