ESTIMATING SUGARCANE YIELDS WITH OY-THAI INTERFACE

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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 v3.5 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 analyzed 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 km^2 in Thailand.

KEYWORD: CANEGRO-DSSAT, Human-Machine Interface, Resource management, Yield Mapping.

Introduction

Government and private agencies annually allocate resources to estimate cane production in Thailand. These estimates are generally made using a simple regression method together with historical records. The estimates do not take into account factors such as rainfall, management options, and soil nutrient dynamics.

To more accurately predict cane production, especially for large areas, a new method, which utilizes crop modeling, is needed. Coupling simulation models that take advantage of geographic information systems (GIS), global positioning systems (GPS), Remote Sensing (RM) technologies, and spatial databases can allow policy makers to predict crop yields more accurately and to take appropriate actions on policies related to sugar exports (Hartkamp *et al.*, 1999).

Modern information technology tools are available for scaling. These tools employ a combination of correlation, extrapolation, and crop modeling techniques to relate patterns across a wide range of temporal and spatial scales.

Crop model development requires a special function where growth and yield patterns are related to biological and physical processes. Together with reasonable spatial databases, a process-oriented crop model may be used to provide scaling-up for ecosystem responses to changes in land uses and policies. Our paper describes the evaluation and use of a PC interface software (OyThai 1.0), which provides a link between a sugarcane model and spatial databases to allow users to estimate large-scale sugarcane yields in Thailand with general applicability to other environments.

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 interview, 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 (CANEGRO-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) boundary, 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 CANEGRO-DSSAT model validation process. The experiment was conducted at three locations in Thailand, namely, Suphanburi (14^{o}N), Khon Kaen (16^{o}N), and Chiang Mai (18^{o}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.

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 characterized as continuous sugarcane fields belonging to large holders. In each province, LANDSAT5 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 AIGIS/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 300MB 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 digitized, with associated DLDSIS (Vearasilp and Songsawat, 1991) soil attribute data sets, maps of administrative boundaries, weather station coverage, 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 grower. Our example in this paper deals with a sugarcane crop that was simulated, using historical weather data. The cultivar selected was ‘U-thong 2’, planted on February 1, at a planting density of 1.5 plants/m^2 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 automatic 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), corresponding to a particular s

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 characterized as the rain-shadow zone, Udonthanee 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.

Satellite image interpretation, with the unsupervised classification method (Lillesand and Kieffer, 1994), revealed that the Udonthanee and Nongbua-Lumpoo provinces contain a total of 83, 200 and 4000 ha of sugarcane plantations (Tables 2). Overall image interpretation gave about ten percent lower estimates of sugarcane area as compared to the Office of Agricultural Economics (OAE) survey (OAE, 2001).

Soil maps, scale 1:100,000 for each province were obtained from the Land Development Department (Vearasilp and Songsawat, 1991). They were then digitized into PC Arc/Info. Five provinces in the Northeast of Thailand were entered into the system, namely: Loie, Nongbua-Lumpoo, Udonthanee, Chaiyaphum, and Khon Kaen. More than 66 unique soil series (alfisols, ultisols, etc.) were identified in the areas.

Soil and climatic diversity within the areas make them good candidates for this study. Their performance 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 area moderately to extremely variable across the province for OC and for ISM at any particular depth, and also decreased substantially in mean value with increasing depth.

Simulated sugarcane dry weight for the rainfed area with additional fertilizer 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 sugarcane yield of 12 SMUs is only 4.9 percent. This compares favorably 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 rainfed 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 area 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 system. In addition, we will continue to improve the model's capacity in simulating the effects of pests on yield, which will allows 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 carries 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 to CANEGRO-DSSAT sugarcane model with spatial databases under a Windows's PC environment. Spatial data requirements area: 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, were 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.

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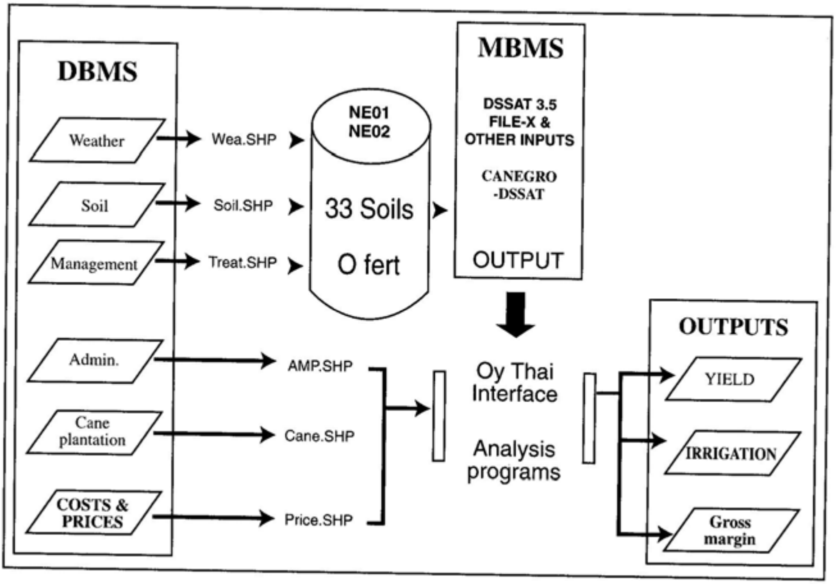

Fig. 1—File structure for the Oy-Thai 1.0 Interface.

Table 1__Average monthly weather data of the three weather zones in northeast Thailand.

Month	Radiation $MJ/m^2/d$			T_{max} (^oC)			T_{min} (^oC)			Rainfall (mm)			Rainy days (days/year)		
	CY	KK	UT	CY	KK	UT	CY	KK	UT	CY	KK	UT	CY	KK	UT
Jan	14.5	16.0	14.7	31.0	30.6	29.6	18.2	16.2	16.3	1.9	4.1	7.3	0.5	0.9	1.5
Feb	14.7	16.4	14.8	33.6	33.0	31.9	20.9	18.9	18.7	18.9	15.1	23.8	1.9	2.2	3.4
Mar	14.9	16.0	14.9	35.6	35.2	34.5	23.0	21.1	21.9	45.6	37.2	47.4	4.0	3.7	4.3
Apr	14.7	16.4	14.6	36.1	35.9	35.4	24.7	23.9	24.3	88.4	62.2	72.7	6.8	7.1	7.5
May	21.4	15.9	21.0	34.8	34.7	34.0	25.0	24.1	24.8	137.4	160.6	193.1	12.9	13.1	15.8
Jun	20.7	14.5	19.9	33.4	33.5	32.9	24.8	24.0	25.1	153.6	176.5	213.9	12.9	15.2	17.8
Jul	20.5	14.3	19.3	32.9	32.8	32.3	24.5	23.7	24.8	99.6	161.2	213.7	13.0	15.9	19.1
Aug	19.9	13.6	18.6	32.4	32.1	31.6	24.2	23.5	24.6	141.0	197.5	285.3	14.5	17.2	21.1
Sep	19.3	13.8	18.6	32.0	31.7	31.6	23.9	23.0	24.2	204.9	247.5	217	17.2	17.5	16.6
Oct	11.4	15.0	11.6	31.3	31.4	31.2	23.2	21.7	22.9	150.6	102.1	80.2	11.2	9.3	8.7
Nov	12.3	15.5	13.1	30.8	30.8	30.2	21.3	18.8	19.6	21.1	16.1	8.1	2.9	2.1	1.8
Dec	13.7	15.4	14.3	29.6	29.8	28.7	18.1	16.1	16.2	5.0	5.2	5.1	0.4	0.9	0.9

NOTE: CY = Chaiyaphum, KK = Khon Kaen, UT = Udonthanee

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

Province	LANDSAT 5 estimated	OAE survey	% Difference
Khon Kaen	56 200	51 600	8.8
Udon	83 200	77 800	6.9
Nongbualum poo	3 300	4 000	-17.6
Loei	20 200	15 400	31.4
Chaiyaphum	32 600	67 700	-51.9
Total	195 500	216 500	-9.7

Note: OAE = Office of Agricultural Economics, Ministry of Agri. & Coop., Thailand.
Overall Bias = -4 200 ha and Root Mean Square Error (RMSE) = 9 400 000 ha.

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.

SMU #	Soil Series name	Weather zone	Simulated		Observed	Percent Different from Observed	
			R	Ir		R	Ir
			t/ha		t/ha	%	
1	Korat	05	14.2	30.4	12.9	10.1	135.7
2	Korat/Phon Phisai	05	15.6	24.2	12.8	21.9	89.1
3	Korat	06	18.8	30.8	13.9	35.3	121.6
4	Roi Et Loamy	08	15.8	35.3	11.9	32.8	196.6
5	Korat	08	14.8	30.8	13.9	6.5	121.6
6	Phon Phisai	08	15.6	25.2	13.1	19.1	92.4
7	Korat/Phon Phisai	08	15.6	24.1	13.9	12.2	73.4
8	Phon Phisai	04	15.6	24.6	16.4	-4.9	50.0
9	Chiang Rai	04	11.7	24.5	13.2	-11.4	85.6
10	Wang Hai	04	15.6	53.5	17.9	-12.8	198.9
11	Ratchaburi	04	15.6	32.1	18.6	-16.1	72.6
12	Chutturat	04	15.6	33.1	17.6	-11.4	88.1
Mean			15.4	30.7	14.7	4.8	109.3

Overall Bias = -2.1 t/ha and root mean square error (RMSE) = 5.8 t/ha