USING A CROP/SOIL MODEL AND GIS TECHNIQUE TO FORECAST SUGAR YIELD IN THE UK.

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ABSTRACT

Sugar yield forecasting is important in the UK for campaign planning and marketing. During the past five years, a process-based sugar beet growth and yield model has been developed incorporating a water-limiting factor which depends on soil texture. This model was tested against sugar yields from both irrigated and rain-fed crops grown on sandy loam soil from 1976-2001 at Broom's Barn. The sugar yields ranged from 5.1 to 15.8 t/ha and simulated yields accounted for 80% of this variance. It was tested again in 2001 and 2002 on different varieties and on different soils at five sites throughout the UK. Results from 2001 were satisfactory at four sites but the fifth site produced a much higher yield than predicted. The reasons for this discrepancy are being investigated. The results in 2002 were similar to those in 2001. A geographic database for soil textures has been built at a resolution of 5x5km in the UK sugar beet growing areas. Other spatial databases for sugar beet fields and weather data are being developed. The Broom's Barn sugar beet growth and yield model will be coupled with these geographic information databases to estimate the sugar yield for management and factory areas.

ABRÉGÉ

L'établissement de prévisions concernant le rendement en sucre des betteraves a toujours été importante en vue de la planification des campagnes et de la vente du produit au Royaume Uni. Au cours des 5 dernières années, un nouveau procédé de culture de betterave a sucre base sur une modélisation du rendement a donc été développé afin d'incorporer les facteurs limitants tels que la texture de la terre, l'hygrométrie et l'espace couvert par les cultures. Ce modèle fut teste en comparaison avec des donnes concernant le rendement en sucre de cultures irriguées ou bien uniquement approvisionnes en eau par la pluie, cultivées dans des sols sablo-limoneux de 1976 a 2001 a Broom's Barn. Les rendements se repartirent entre 5.1 et 15.8 t/ha. La simulation et le rendement concordèrent pour 80% de la variance dans les champs testes. Ce modèle fut donc teste plus avant en 2001 et 2002 avec l'utilisation de différents types de terre sur 5 sites tests. Les résultats de 2001 furent satisfaisants sur 4 des sites car le cinquième vu son rendement atteindre une valeur beaucoup plus élevée que prévu. Les raisons de cette différence sont toujours étudiées a ce jour. Une base de données géographique des types de sols fut établie avec une résolution de 5 sur 5km sur les zones de culture de betterave a sucre au Royaume Uni. D'autres bases de données spatiales de la distribution des

champs de betterave a sucre et des conditions météorologiques sont actuellement en développement. Les rendements des cultures a Broom's Barn et le modèle de prévision seront couples avec ces informations géographiques afin d'estimer le rendement en sucre pour gérer efficacement les aires de production.

KURZFASSUNG

Die Vorausschätzung des Zuckerrübenertrags ist seit jeher in Großbritannien für die Planung von Kampagne und Marketing wichtig gewesen. Während der vergangenen fünf Jahre wurde ein prozessbasiertes Modell für Zuckerrübenwachstum und -ertrag entwickelt, das einen vom Bodentyp, Niederschlag und der Entwicklung der Bestandes abhängigen wasserbegrenzenden Faktor berücksichtigt. Dieses Modell wurde anhand der Zuckererträge von bewässerten und nicht bewässerten Beständen getestet, die 1976 - 2001 auf sandigem Lehmboden bei Broom's Barn angebaut wurden. Die Erträge von 5,1 bis 15,8 t/ha. Die vom Modell simulierten Erträge entsprachen 80 % der Streuung bei den beobachteten Erträgen. Dieses Modell wurde 2001 weiter getestet und wird 2002 unter Einbeziehung einer Reihe unterschiedlicher Bodentypen an fünf Standorten getestet. Die Ergebnisse von 2001 waren für vier Standorte zufriedenstellend, aber an dem fünften Standort wurde ein sehr viel höherer Ertrag gebildet als prognostiziert. Die Gründe für diese Diskrepanz werden momentan untersucht. Eine geografische Datenbank für Bodentypen wurde mit einer Auflösung von 5x5km für die Zuckerrübenanbaugebiete Großbritanniens geschaffen. Andere räumliche Datenbanken für Zuckerrübenfelder und Witterungsdaten befinden sich in der Entwicklung. Das Modell für Zuckerrübenwachstum und -ertrag von Broom's Barn wird mit diesen geografischen Informationsdatenbanken verknüpft, um den Zuckerertrag für Bewirtschaftungs- und Fabrikeinzugsgebiete zu schätzen.

INTRODUCTION

Accurate forecasts of sugar yields are important with regard to optimising the efficiency, cost-effectiveness and timeliness of the campaign to the benefit of both growers and the processors. Early forecasting of sugar production also plays an important role in planning the production so as to increase the overall profitability. In the UK, British Sugar plc adopts two methods to provide the pre-harvest estimates of the national sugar production. The first method relies on two or three helicopter over-flights in the middle of the growing season to measure foliage cover. This cover index is then used to calculate the canopy intercepted radiation (Scott and Jaggard, 1992). From late June onwards this is used to produce a national sugar yield forecast. This method does not provide sugar yield forecasting at individual factories nor does it distinguish the spatial and temporal variations caused by different soil types, rainfall patterns and sowing dates. The second method is based on pre-harvest crop samples taken manually from representative fields at weekly intervals during August, September and sometimes October. The statistical relationship derived in previous years between sampled material and delivered sugar yield is used to estimate total sugar yield over the country (Church and Gnanasakthy, 1983).

This method is labour-intensive and does not give any insight into the causes of yearly variations in production.

SUGAR BEET GROWTH MODEL

Climatic variations are the dominant factors determining growth and sugar yield in sugar beet (Scott and Jaggard, 1992). A process-based crop growth and yield simulation model driven by climatic variables has recently been developed at Broom's Barn (Jaggard and Werker, 1999).

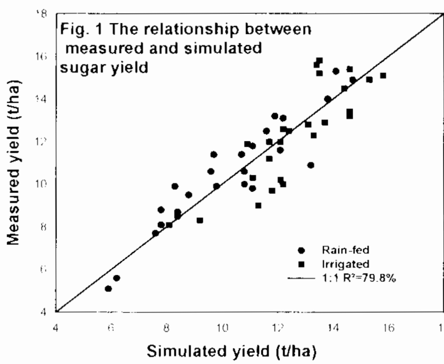


Fig. 1 The relationship between measured and simulated sugar yield

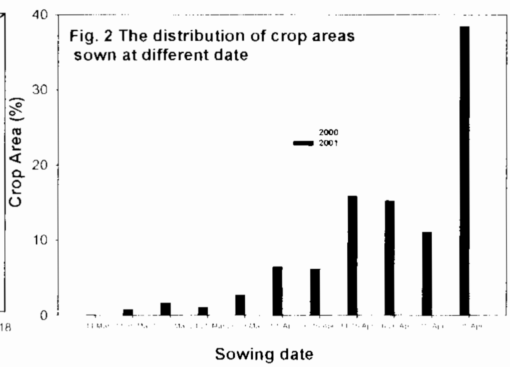


Fig. 2 The distribution of crop areas sown at different date

This model was tested against sugar yields from irrigated and rain-fed crops grown on sandy loam between 1976 and 2001 at Broom's Barn. The yields ranged from 5.1 to 15.8 t/ha. The simulated yields accounted for 80% of this variance (Fig 1). It was again tested in 2001 and 2002 on different varieties and on different soil textures at five sites throughout the UK. On four sites, the agreement between observed and simulated crop cover, growth and yield were good. The large difference between observed and simulated yields on the silty soil is still being investigated.

SPATIAL AND TEMPORAL VARIATION

Every year beet growers report to British Sugar plc the locations of about 22000 beet fields, the area sown and the distribution of the sowing dates. The locations are uniquely identified and can be mapped and the distribution of sowing dates in 2000 and 2001 is shown in Fig. 2.

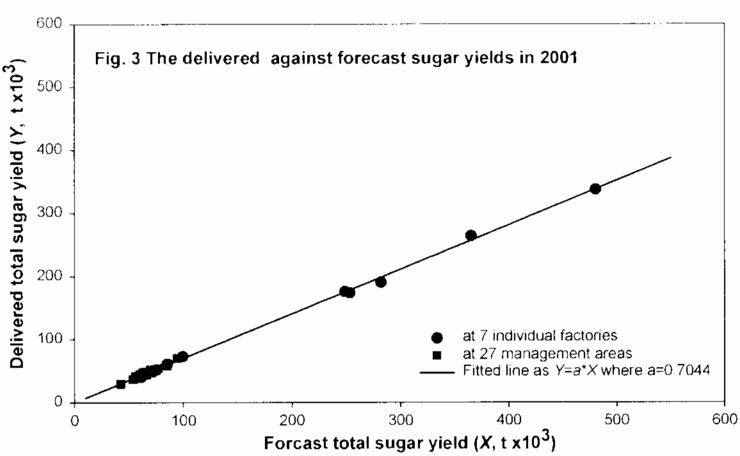
Digital soil maps for the UK are expensive and the underlying resolution of the observations is course. So, we used information from 9482 representative fields surveyed by British Sugar staff between 1986 and 2001. The trained surveyors recorded field location and the main top soil texture in each field. They allocated the soils to one of 15 different textures, but for our purposes these have been condensed into 5 groups. From these 9482 fields, we assigned a dominant soil texture to each 5x5km grid where beet is grown. On the basis of these textures, each area has been allocated an available water capacity. Using the soil texture type data from surveyed beet fields instead of from the published soil maps avoids the problem that many farmers select which fields to allocate to beet on the basis of very local differences in soil texture, which affects harvestability.

INTEGRATING THE GROWTH MODEL INTO A GEOSPATIAL DATABASE

Proprietary Geographic Information System (GIS) software are important tools to capture, store, manipulate, process and display spatial data. However, they do not offer easy interfaces to simulate with models the complex processes which incorporate spatial elements. The Broom's Barn growth model, however, when programmed in a high level computer language, can act as a standalone modelling system. Therefore coupling the growth model with a GIS will create a yield forecast system.

The geospatial database consists of separate tables in Microsoft Access. One table contains the soil textures and one contains the daily temperature, global radiation, precipitation and grass potential ET at representative sites. Rainfall is normally considered more variable and thus a separate table can be created at more sites to take account of this larger variability. One table contains the field locations, field sizes, sowing dates, factory codes, etc. The growth model programmed in Visual Basic simulates the sugar yield per hectare for each field, using the soil texture type and daily weather values linked to this field. These yields are then aggregated on an area basis. Since the harvesting date for each field is not recorded, the harvesting date is nominally fixed as 31 October for all beet fields although harvesting lasts from September to January.

Fig. 3 shows the forecast against sugar delivered from individual management areas and factories in 2001. In this case all the weather data were recorded at Broom's Barn. Obviously, the forecast was more than the actual sugar yield delivered to the factories. However, the over-prediction was relatively consistent, indicating the forecasting system is reliable and the delivered yield is about 70% of the forecast yield. This downward adjustment is understandable: forecast yields are the potential yields predicted for the perfect crop, which is uniformly established, free from weeds, pests and diseases, and harvested efficiently. Scott and Jaggard (1992) assigned the 30% reduction in delivered yields to no less than six factors.



CONCLUSION

In the UK, sugar yields are affected by variations in the distribution of different soil textures, weather patterns and the crop areas sown on different dates. The Broom's Barn beet growth and yield model is proving reasonably robust on different soil types. This simulation model, when integrated with a geospatial database system, is capable of taking account of these spatial and temporal variations, and should form a versatile sugar yield forecasting system for the future.

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