# SITE-SPECIFIC MODELING OF CORN YIELD IN THE SE COASTAL PLAIN*

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ABSTRACT

When site-specific farming became technologically feasible, existing crop models made computer simulation a natural choice for predicting yield under various combinations of soil, weather, and management. However, modeling for site-specific farming may require both greater accuracy and sensitivity to more parameters than in current models. Results demonstrate that the DSSAT corn model appears unexpectedly insensitive to soil type, depth to clay, nitrogen, and plant population, suggesting areas for attention. It appears appropriately sensitive to rainfall, indicating sensitivity to soil water content is generally correct. However, the model was less sensitive to the curve number procedure that calculates runoff. The model also responds to maximum air temperature, but crop temperature varies more than air temperature. Routines may be needed to accommodate within-field redistribution of runoff and to calculate crop temperature from water stress. Model accuracy issues aside, accommodating spatial inputs and model runs requires enhanced interfaces. These suggested enhancements to crop growth models would improve applicability for site-specific agriculture.

## 1.0 INTRODUCTION

## 1 REQUIREMENTS OF MODELS

To be fully functional for use in site-specific farming, models need to be able to use and produce spatial data, need to account for and describe the processes that are important to site-specific farming, and need to be sufficiently accurate that their results can be relied upon. Whether models successfully address all these issues will determine their value in the long term. A description of the 1995 state of the art of modeling for site-specific agriculture was made by Sadler and Russell (1997), and steady progress has been made since then. Here, the authors examine several issues that appear critical for success under conditions common to the SE USA Coastal Plain and similar regions of the world.

1.1.1 Interface Issues. Nearly all modeling work has been done using the assumption of 1-dimensional processes, specifically vertical. Site-specific farming requires the addition of the two horizontal dimensions. Rather than completely restructure models to do this, most work has applied 1-D models at multiple points in space. This appears to be both efficient and to have potential for success, but causes some difficulties accounting for some processes that inherently occur in the spatial dimensions, as discussed below.

Managing spatial data has motivated the development of geographic information systems (GIS). Most applications of modeling to site-specific agriculture have combined the 1-D models with a

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GIS or built some GIS features into the model's user interface. Examples range from very simple models, run entirely within the GIS, to specialized interfaces to pass data between the model and GIS. Several examples of this work were summarized by Sadler and Russell (1997), and much progress in this area can be seen in this proceedings.

1.1.2 Process Issues. Models evolve incrementally; developers start by describing the relationships that are both tractable and important to the model objectives. Therefore, embodied in every model is a suite of assumptions about what factors and processes are important enough to include. These assumptions constrain the proper application of a model to conditions for which the assumptions are justified. For instance, a crop growth and yield model is likely to have less technical rigor in the computation of nitrate leaching than would a groundwater loading model. This would make the former less attractive than the latter for studying water quality. Such observations, though trivially obvious to the developers, are sometimes ignored by, or are even unknown to, users with different objectives.

Development of 1-D models would understandably place less emphasis on processes inherently important only to the horizontal dimensions. One such process rarely addressed except externally to 1-D models, but that may be significantly important to site-specific modeling, is the horizontal transfer of water via runoff or flow along subsoil horizons. Another, the opportunity for site-specific pesticide use, may ultimately make predation and competition effects very important to site-specific modeling. Livestock feeding patterns, which may be distinctly spatial for reasons known only to the livestock, may be critical for models useful in site-specific forage management. Many such examples have been listed (Sadler and Russell, 1997), and no consensus seems to be in sight as to what constitutes an important process.

1.1.3 Accuracy Issues. Accuracy of models has been both an objective and a stumbling block for model developers and model users, and accuracy requirements are as varied as model objectives. It stands to reason that if one desires to create a fertilizer recommendation map using a model to optimize nitrogen applications, then the model must accurately simulate the effect of nitrogen on yield for all combinations expected for a range of soil, weather, and nitrogen. This implies that if a model does not account for a factor, the real system's sensitivity must be independent of that factor. A working definition, then, of accuracy requirements is that models must be appropriately sensitive to all important parameters (Sadler and Russell, 1997). This sensitivity means that both the average value and derivative with respect to the managed input must be accurate within tolerances appropriate for the objective.

1.1.4 Working Pattern for a Site-Specific Model. A model applicable to site-specific agriculture should handle spatial data well, should account for all factors considered important or manageable, and be accurate enough that decisions made using it are the best ones.

## .2 FIELD STUDIES AND METHODS

Since 1985, researchers at the USDA-ARS Coastal Plains Soil, Water, and Plant Research Center at Florence, SC, have mapped field crop yields on a 6-ha field with soil variation typical of regional soils. A detailed description of the soils and research history can be found in Karlen et al. (1990) and Sadler et al. (1995b). To date, the field has been farmed to match conventional, whole-field culture in an attempt to document inherent variability prior to attempting to manage variability. In the 13 years, 7 corn, 1 grain sorghum, 5 wheat, and 4 soybean crops have been mapped, initially with stop-and-weigh techniques, and more recently with a combine yield monitor. Detailed soil water use and other measurements were made during the 1987 wheat and 1993 corn seasons (Sadler et al., 1995a). The series of corn yield maps and collateral data will be used here to evaluate model sensitivity.

The DSSAT v3 corn growth and yield model (Tsuji et al., 1994) was used to simulate corn yield after the fact. Weather data were taken from an on-site automated station. Soil files were constructed from typical pedon descriptions for the specific soils in the field (USDA-SCS, 1984). Best estimates of all parameters were used to make null runs to compare to runs with varied parameters.

### 1.3 CANDIDATES FOR 'IMPORTANT' VARIABLES

A basis for judging importance of variables can be obtained from a consideration of local experiences and of technical capabilities of VRT equipment. For soils in the Southeast region, soil map unit classification is a logical first choice, because of data availability and because expected yields vary markedly among map units. Beyond that, the depth of the transition from sandy to clayey layers is a prominent determinant of the soil mapping unit, so it is a logical and easily measured candidate for describing within-unit variability. Measurements (Sadler et al., 1995a) suggest that water supply and crop temperature should be additional candidates for study.

The primary candidates for variable-rate management in rainfed agriculture are usually fertilizer or seeding rate recommendations. Therefore, it is important that models demonstrate accuracy and appropriate sensitivity to these variables if the models are to be used in setting recommendations for the variables.

## 2.0 SENSITIVITY ANALYSES

### 2. SENSITIVITY TO CANDIDATE CAUSES OF VARIABILITY

2.1.1 Soil Map Unit. Figure 1 shows the simulated yield as a function of mean measured yield for each map unit. As can be seen, the model functions better as a central tendency estimator than it does as a variance estimator, both within and among years and within soils. Clearly, the causes of yield variation were not represented by the inputs and processes of the model for these conditions. This suggests that further work will be needed to achieve full success in site-specific applications.

2.1.2 Depth to Clay Layer. To create the soil profiles with varied depth to clay layers, the typical pedon description was copied and the thickness of the E horizon was varied to achieve the range observed in the field. Figure 2 shows the sensitivity of modeled corn yield to depth to clay for the NkA soil. Historical measured yields (Sadler et al., 1995b) for the Nka vs. NoA and NcA vs. NbA map units show a consistent benefit to the thicker sandy layer. Regression analysis on 1988 measured corn yields showed a 2.5 kg/ha increase per 1 cm increase in depth to clay for NkA, and in excess of 100 kg/ha per 1 cm increase for NoA (Sadler et al., 1995b).

2.1.3 Water Supply. Sensitivity to water supply was determined using variation in rainfall and in curve number. Figure 3 shows the sensitivity of simulated corn yield to rainfall for all years and four soils. The two extremes are demonstrated by 1995, where the water supply had reached a plateau, and by the drought years 1986 and 1993. The apparently inconsistent increases in 1986 yields with reduced rainfall are explained by delayed germination, causing those scenarios to have discretely different water supply inputs. Field observations, measurements, and simulations (data not shown) suggest the model overestimates infiltration with the curve number procedure, but CERES-Maize model runs using Green-Ampt infiltration calculations accounted for only half the yield error (Stone and Sadler, 1991).

Sensitivity of the corn model in DSSAT v3 shown here suggests a plausible sensitivity to water supply but further suggests that the procedures to calculate the water balance may need to be examined.

2.1.4 Temperature. Spatial measurements of canopy temperature in 1993 (Sadler et al., 1995a) showed extreme spatial variation, suggesting that within-field variation in crop temperature would merit examination as a cause of differential crop growth and yield. The cause of the variation in crop temperature was assumed to be differential water stress, which was markedly variable at eight measured locations. The effect of canopy temperature would presumably be limited to the maxiumum temperature experienced, because nighttime radiative forcing is essentially neutral to water stress. Figure 4 shows the sensitivity of the model to changes in maximum air temperature, which drives the crop development calculations. For some years, the sensitivity appears to be sufficient to warrant further examination of the difficulties and benefits that might accrue if a more rigorous canopy temperature routine were added to the model.

The known effect of temperature on crop development rates, coupled with the observed spatial temperature and observed variation in tasseling and maturation (Sadler et al., 1995a), required that sensitivity of this additional effect of temperature be examined. The increased temperatures accelerated development in the simulations (data not shown), as expected from the maturation routine's dependence on growing degree units. However, observations (Sadler et al., 1995a) showed up to 3 weeks delayed development in areas with higher canopy temperatures. This suggests a routine to account for water stress by temperature interactions may improve the applicability of the model to site-specific farming.

## 2.2 SENSITIVITY TO CANDIDATES FOR MANAGEMENT

2.2.1 Nitrogen Supply. The sensitivity to nitrogen fertilizer was examined using variable sidedress applications at 50 kg/ha above and below the actual aplication. As seen in Figure 5, the sensitivity to varied fertilizer suggests that nitrogen stress does not appear to be the limiting factor for model calculations.

2.2.2 Plant Population. Sensitivity to varied plant population is shown in Figure 6. There is relatively little sensitivity to population, and the essentially flat response to extremely high populations suggests that competition for water and possibly light or other resources should be evaluated for inclusion in the model.

## 3.0 SUMMARY AND CONCLUSIONS

Model sensitivity to several candidate parameters suggests potential directions for model evolution to improve suitability for use under conditions common to sandy soils of the SE USA Coastal Plain and similar regions of the world.

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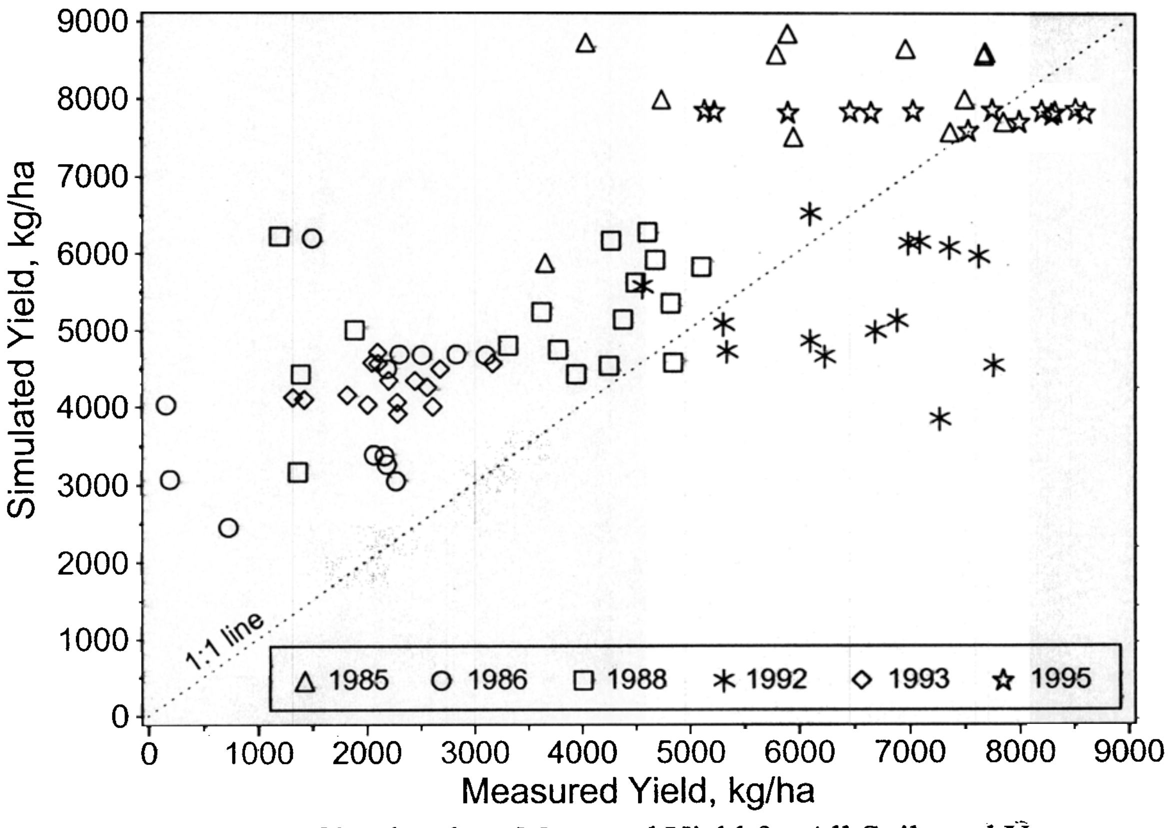


Figure 1. Simulated vs. Measured Yield for All Soils and Years.

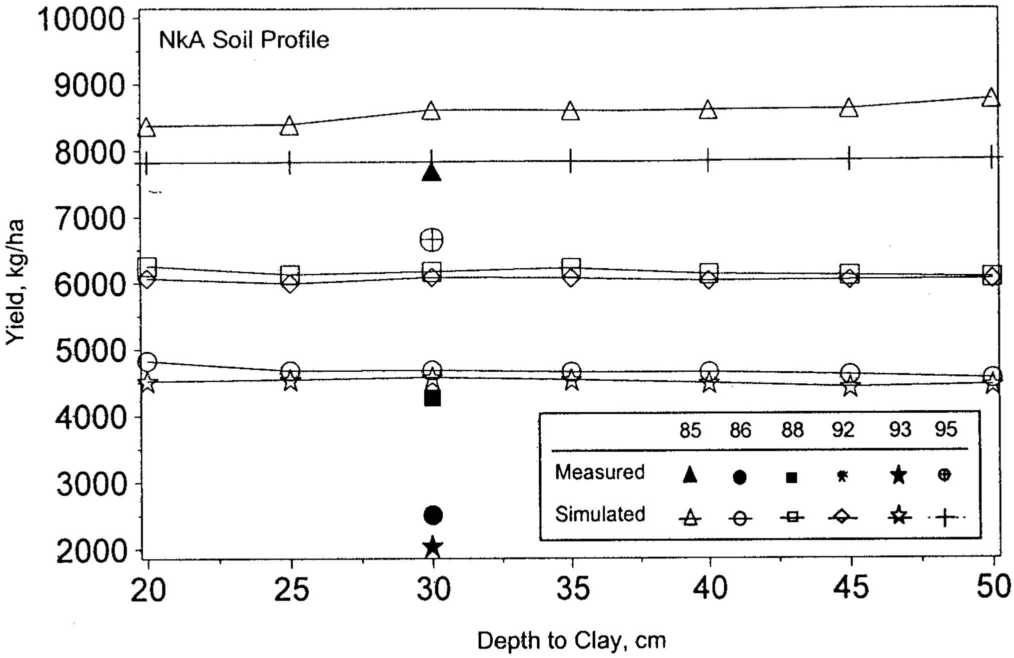

Figure 2. Yield as Affected by Depth to Clay for NkA.

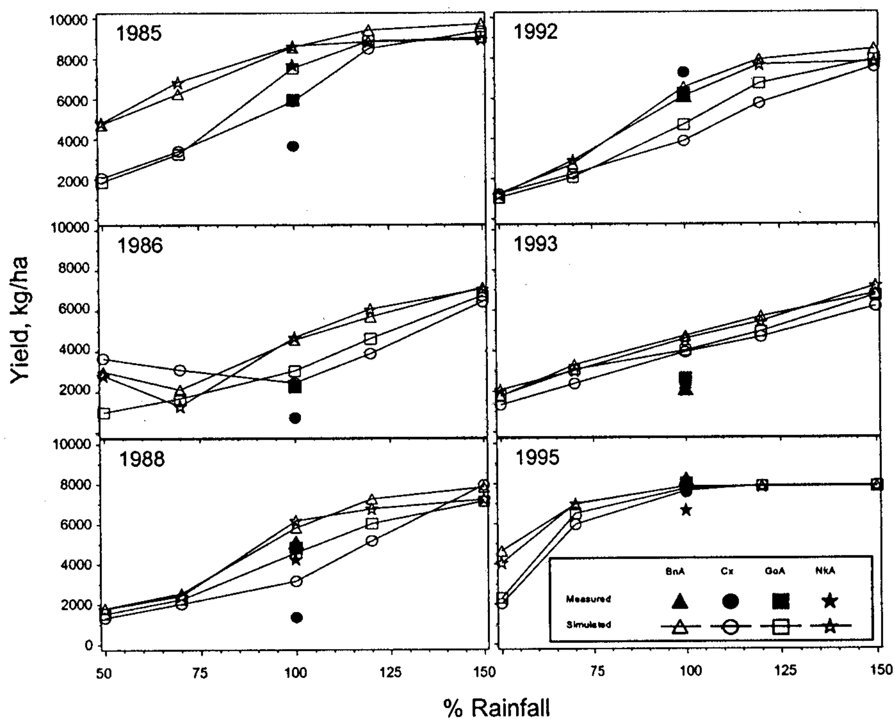

Figure 3. Yield as Affected by Rainfall.

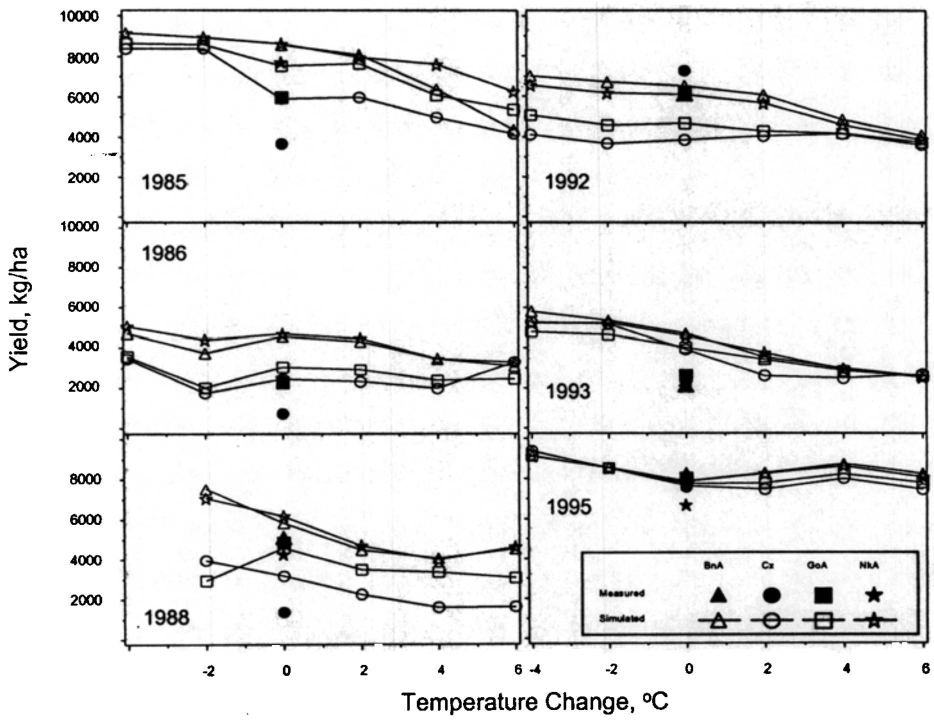


Figure 4. Yield as Affected by Maximum Air Temperature.

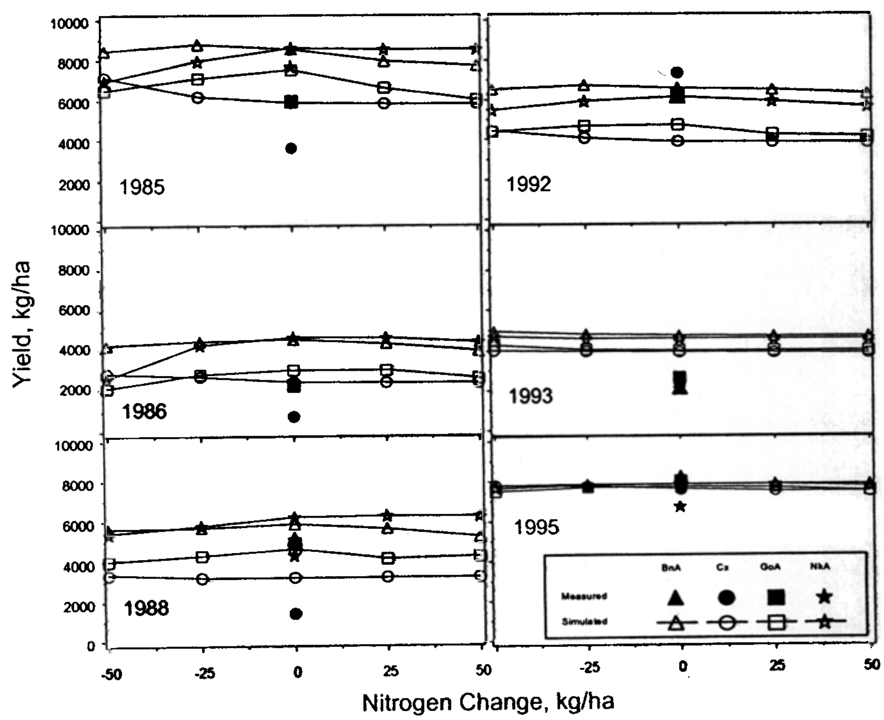


Figure 5. Yield as Affected by Nitrogen.

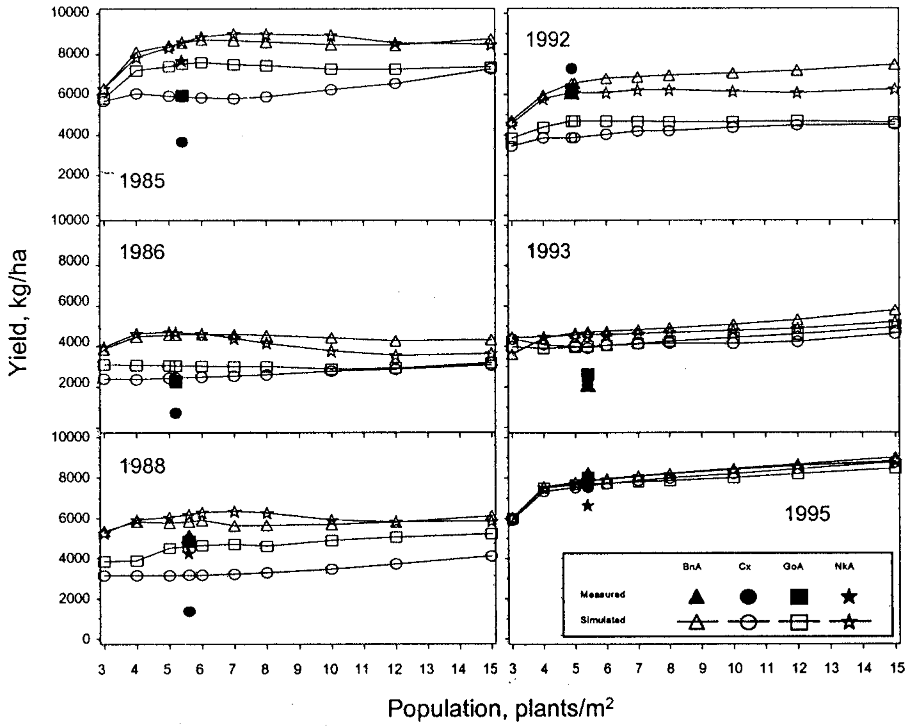


Figure 6. Yield as Affected by Plant Population.

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