A GIS INTERFACE FOR COTTON GROWTH MODELS THAT INCORPORATES MIDSEASON ADJUSTMENTS
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Abstract

To improve site-specific management (SSM) for agriculture, there is a need to predict responses to management decisions and provide information regarding individual input variables on a site-specific basis. This can be achieved by linking a crop growth model to a geographical information system (GIS). Additionally, it is important that the GIS interface and model be capable of accommodating actual field measurements to calibrate the model to actual field observations. By allowing midseason adjustments into crop simulations, factors that affect crop growth but are not included in the model that cause the simulation to diverge from actual values can be considered. Linking a crop growth model to a GIS can also be a tool to develop variable-rate prescription application maps that include both the time and amount needed to apply.

The objective of this research was to develop a modified ArcView GIS interface for cotton growth models that incorporated midseason height adjustments and would allow for the generation of variable rate application maps. The cotton model used to develop the interface was GOSSYM, a management –oriented cotton crop simulation model developed by the USDA-ARS-CSRU (Crop Simulation Research Unit) at Mississippi State. It is not intended for this interface to be used solely with a specific crop growth model, but that it be robust enough to be used with a variety of models as they become available with only minor adjustments.

Introduction

Many current site-specific management (SSM) practices rely on information after a management practice has been implemented. The most common source is yield monitors that provide data on how a combination of management practices performed during the past growing season. Unfortunately, the information becomes available too late to change management decisions during the growing season. If each growing season were exactly the same this method would be sufficient, however, each growing season has a unique set of conditions that will ultimately affect the outcome of a crop. Additionally, this method does not provide for information regarding the effect of a single input variable, only the combination of management decisions. Ideally, the best method of evaluating management decisions is to predict the response of a crop to an input variable and to determine if and how the relevant variable can be managed in a cost-efficient manner. The ability to predict responses to management decisions and to provide information regarding individual input variables is achieved through crop growth models.

Crop models are able to predict the outcome of crops given the required input information. From a SSM standpoint, crop models are valuable in aiding the management process during a growing season. A grower is prepared in advance when to expect certain physiological occurrences, reducing the amount of guesswork in managing a crop. Additionally, models serve as a surrogate for real experimentation. By altering the input parameters and implementing the model with iterations, the user can identify the effect of individual input parameters. Likely to be the most valuable aspect of crop models is the potential use with a geographical information system (GIS). The potential value in linking a crop model with a GIS is that the information becomes available for variable rate applications as well as site-specific economic evaluation of management decisions.

A potential drawback to these models; however, is the fact that all the factors affecting crop growth that have not been well modeled are not included in simulations. The absence of this information, some of which is vital in predicting crop growth, can cause a divergence from actual field values. In such cases it becomes necessary to provide actual field measurements to the model so that it can calibrate itself to theme observations. Such observations may improve the predictions of the model.

Cotton is a very important crop. In a typical year, U.S. cotton farmers invest more than $652 million in fertilizers, $762 million in agricultural chemicals. Because of its economic importance, cotton is an attractive crop for implementing an integrated SSM system to improve management practices. By incorporating it into the daily decision making of growers, it will allow for more effective management of a crop on a SSM basis. With a model to spatially organize all variable rate information and to predict yield based on these variable rate inputs, the grower can determine if a particular application will economically benefit the enterprise. The model simplifies multi-dimensional data that is difficult for a human to process into a representative one-dimensional value. Additionally, models encode detailed scientific knowledge. The GIS interface allows for a visual display of this information to assess the spatial extent of model inputs. For instance, if two acres of a 100-acre field requires fertilization, the grower may choose not to fertilize at all. The cost of driving equipment to that part of the field may be

greater than the return if that portion of the field is remedied. These advantages of SSM modeling for cotton offer a more effective way for a grower to consider the abundant information available for making midseason management decisions.

Discussion

An explanation of the GOSSYM cotton growth model and the USDA-ARS GIS interface is warranted at this point. The crop model to be evaluated for this research is GOSSYM (GOSsypium Si(Y)Mulator) model for cotton (Krieg, et al., 1996). This model is a dynamic, daily simulator of the development and growth of the cotton plant. GOSSYM requires the following model inputs:

- Daily weather-temperature, rainfall, radiation, and wind
- Initial soil fertility status
- Soil physical properties-bulk density, hydraulic conductivity, and moisture retention characteristics
- Cultural inputs-row spacing, cultivar, plant density, fertilizer, and plant growth regulators applications, etc.

The model reports daily plant parameters including plant height, nodes, square, green and open boll counts, nitrogen, water and carbohydrate stresses, etc. At the end of a full season run, GOSSYM produces a summary on the date of maturity, plant height, and yield.
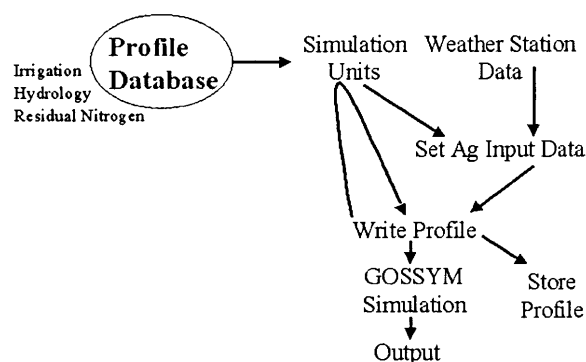
An initial ArcView GIS interface for the GOSSYM model was provided by USDA-ARS Crop Simulation Research Unit at Mississippi State. This interface was developed to allow the user to create boundaries that define unique areas of the field and allow for individual simulation of these areas. To build a profile, the GOSSYM terminology for a file containing all information required to perform a simulation, the user is first required to provide the geo-referenced boundary of a field and the geo-referenced locations of weather stations. The user then initializes a field table, a database file that contains fields for field parameters such as row width and spacing, the historical weather file, planting data and density, etc… The field can be subdivided into simulation units based on the union of one other polygon theme. This procedure can be performed multiple times to further subdivide the field.

Initial soils and hydrology information is stored in other tables that reference source files. The user builds a polygon theme from point samples and/or digitized soil maps. Data required by GOSSYM such as percent sand, silt, and clay is stored as delimited text files with the association GPS coordinates. To enter Ag Input data, information about the cultural inputs such as fertilizer and plant growth regulator, the user inputs the type, date, amount, etc, for each field. The information is entered on a field basis and cannot be entered for each simulation unit. In addition to cultural inputs, pivot irrigation information is also considered.

For a simulation, the GOSSYM code is placed as functions in a dynamic link library (DLL) and is called directly from ArcView. For each simulation unit created, a separate profile is created and the filename to a function in GOSSYM. This results in the generation of a multitude of files, one for each simulation unit. Each site-specific soil sample is sent to a function in the DLL that replaces the current value of that respective variable. The simulation is then executed with the same GUI windows as the Windows interface of GOSSYM. The final results are retrieved at the end of a simulation and can be displayed in ArcView as a polygon theme.

USDA Interface

Many limitations exist within the interface supplied by the USDA-ARS that prohibit the organization and creation of variable rate applications. In addition, the generation of a multitude of files for each simulation requires abundant storage space and careful file management. Improvements are warranted for the user friendliness of the model. Despite limitations, this model interface demonstrates the capabilities of using spatial data with crop models to improve the usability of simulated data.

Interface Modifications

The initial ArcView GIS interface for the GOSSYM model was provided by USDA-ARS Crop Simulation Research Unit at Mississippi State. The field could be further subdivided by soil and hydrology information; however, the interface did not allow for the subdivision of fields into simulation units based on other site-specific inputs that would be accumulated in SSM. For instance, a variable rate fertilizer application could not be used to subdivide a field. The foundation for accommodating all SSM inputs was a new organization of the information required to perform a GOSSYM simulation.

With the new modified GIS interface, all information for field simulations was organized within one database except for the weather file, which was stored for each corresponding weather station and one Ag Input database per field. Site-specific inputs requiring the generation of new simulation units did not result in the creation of a new corresponding set of files. Alternatively, a new record was created in a database containing all of the previous information as well as the new values provided by the site-specific input. This new organization greatly simplified retrieval and data entry, and allowed the user to view all simulation information with one mouse click. The Ag Input data was changed to allow the user to define an application. For that application, the polygon theme defining the rates was used to subdivide the field and stored in the simulation unit database while a reference was made in the field name to the parameters defining the application.

Another major limitation to the interface was that it did not accommodate midseason adjustments. Because of the importance in making mepiquat chloride prescription maps, the interface was modified to accommodate mid-season height adjustments. In the simulation unit table, a field was created for each date that a height measurement was made. Similar to the Ag Input data, the field name contained a reference declaring the data as a midseason adjustment and referring to the date of the measurement.

The most important aspect of the new organization is the robustness of the interface. Simple modifications would allow the use of this interface with other cotton growth models that may become available in the future. Because all profile information is written to a file instead of requiring the placement of information with the aid of new functions in the DLL, the model need only be adjusted to develop the files required by the new model. Also, parameters required by a new model not considered by GOSSYM can easily be added.

The New Interface

Several menu items and dialog boxes guide the user in entering the data required for a GOSSYM simulation. The sequence of events is set up so that the user begins at a level where the entire farm can be viewed and information specific to the farm can be viewed (Fig. 1). At this level, the user can enter information regarding weather station, including the geo-referenced location and the filename containing the weather data.

A simulation event can be performed on one field at a time and requires the cloning of one field boundary into a field view. Simultaneously, the field table is initialized to create a field for each profile entry required by GOSSYM (Fig. 2). Once the table is initialized, the required profile information from the farm level is copied to the new table. Any changes

in the field table are reflected also at the farm level but changes made at the farm level are not reflected at the field level. For each field contained in the farm, a unique field name must be supplied.

Profile data is entered with the aid of a dialog box. For any data that could potentially be SSM data, the user labels it as such (Fig. 3). A data source must be specified as one or the other. While selecting the initial soils or hydrology data source, the user has three options. The first is to use a file already supplied by GOSSYM. The other options are to enter the data into a spreadsheet to create a user-defined file or to use SSM data.
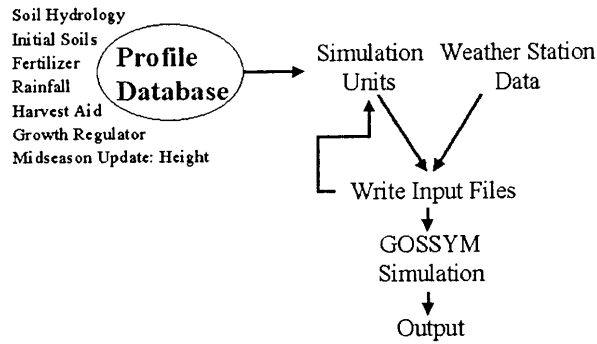
Next, the user must enter the SSM data that was selected in the Profile Dialog and any other accompanying SSM data that may be available (Fig. 4). At this point multiple types of SSM data that can be included into a GOSSYM simulation are available including fertilizer applications, plant growth regulator applications, rainfall data, and mid-season height adjustment measurements. Each data source must be in the format of polygon theme with a polygon for each unique section of the field (Fig. 5). At this point, point data is not supported in the interface. However, polygons can be generated from sparse point data with the aid of included scripts.

Once all of the profile information, SSM and non-SSM, has been included in the field view, simulation units must be created. (Fig. 6) These units are created based on the union of the boundaries of all of the SSM polygon themes. Because some simulation units may be smaller than the desired size or smaller than a variable rate application swath, the user can define the smallest desirable size of unit. It is also possible for the user to define her or his own set of simulation boundaries. In such cases, area-weighted averages are calculated.

To perform a simulation, a majority of the USDA-ARS interface was maintained. However, when a simulation is executed, only one profile is written for the first simulation unit. If any Ag Input or midseason update data exists, that information is also written to a file. Instead of generating a unique set of files for each simulation unit, changed values are overwritten in these same files. Variable rate rainfall is handled by a function within the DLL that replaces the array value for rainfall on a given date to that given by a SSM input. This capability also allows for the incorporation of hydrology algorithms.

Data is retrieved in the same method as in the USDA-ARS model. The results are stored in a database file and can be used to display the values for each simulation unit (Fig. 7). An example of simulated cotton yield with and without midseason adjustments is shown in Figures 8 and 9.

New Interface

Soil Hydrology
Initial Soils
Fertilizer
Rainfall
Harvest Aid
Growth Regulator
Midseason Update: Height

Profile Database

Simulation Units   Weather Station Data
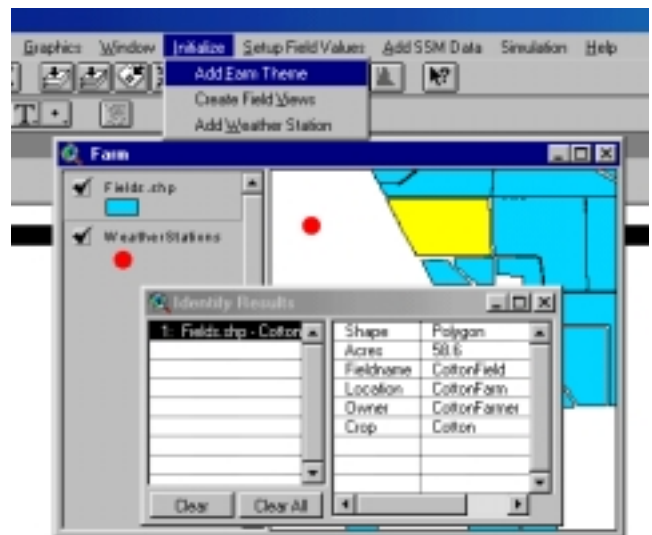
Write Input Files

GOSSYM Simulation

Output

Figure 1. A view of the farm with one field selected and its association record data. Add Farm Theme guides a user in importing the boundaries of the fields in a farm view and initializing the associated table. The circles represent the location of weather stations.
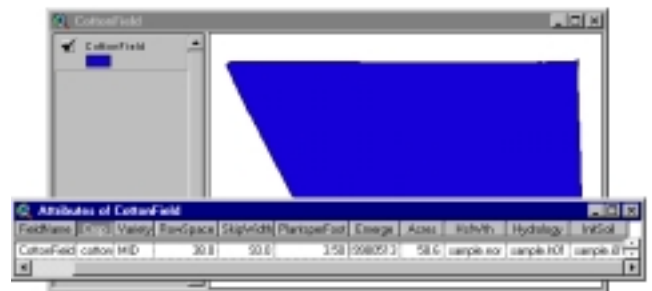
Future Developments

By utilizing midseason adjustments in crop simulations, the effect of factors that affect crop growth, but are not included in the model can be considered. Linking a crop growth model to a GIS can also be a tool to develop variable-rate prescription application maps that include both the timing and rate of applications. Progress has been made toward using the simulated estimations of plant weight and height to determine the timing and rate of mepiquat chloride applications. The relationships existing in GOSSYM with the inclusion of midseason adjustments could help improve the actual concentration estimations and to predict if and when an application should be applied. Lining this information to a GIS would result in an applications map that could serve as such or be used to do further evaluations such as economic and yield analysis.

Figure 2. Field view used to generate simulation units along with the initialized table that will hold all simulation information.

References

Akins, D.C., J. L. Willers, J. M. McKinion, S. B. Turner, F. D. Whisler and J. Varco. 1999. Integrating GIS into precision crop management. Proceedings of the 1999 Beltwide Cotton Conferences. Pp 395-399.

Krieg, Daniel R., Rober J. Lascano, Scott A. Staggenborg. 1996. Determining cotton water use in aSemiarid Climate with the GOSSYM Cotton Simulation Model. Agronomy Journal. 88: 740-745.

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Figure 3. Dialog box to aid user in data entry for the profile.

Figure 4. Selection of SSM data that can be included into a GOSSYM simulation. The list button displays the variables that were declared in the profile editor as SSM.
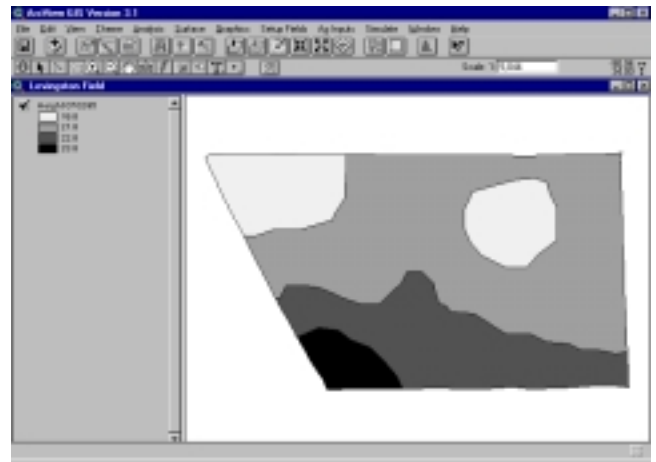

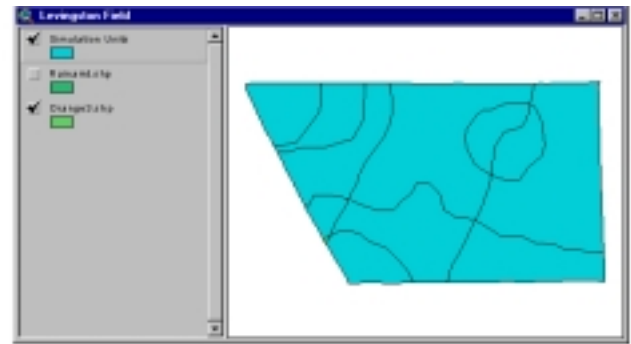Figure. 5. Example of a height map in the form of an ArcView polygon theme.

Figure. 6. Example Simulation units generated from a height map and a fertilizer application map.
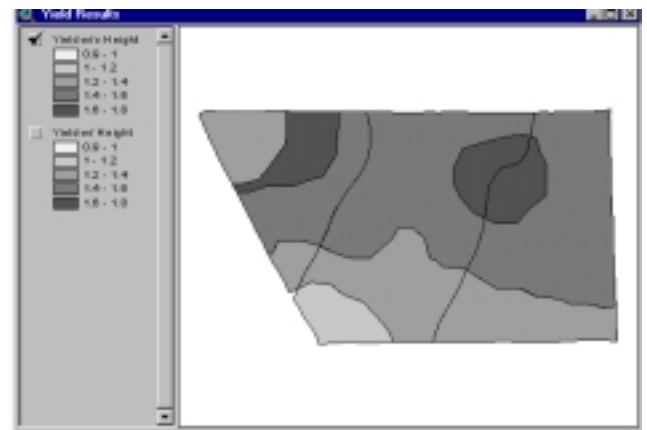

Figure 7. In this simulation, no height information was included. The classification labels have a 0.2 bale per acre increment with minimum 0.9 and maximum 1.8.
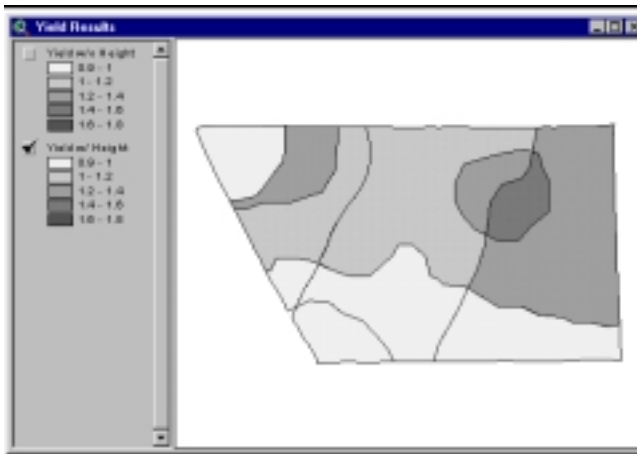
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Figure 8. In this simulation, height information was included with five measurement dates. The classification interval is the same as in figure 7.