GEOSPATIAL DECISION SUPPORT FOR SEED COMPANIES IN THE CORN BELT

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ABSTRACT

As bioinformatics applications unfold in the seed industry, new applications emerge for mapping, analysis, and interpretation of cultivar performance across multiple environments in the Corn Belt. Genotype x environment interactions readily translate into matching the traits of corn hybrids with soil properties and microclimatic parameters of croplands. Using relative maturity days, growing degree-days, and frost-free periods, soil survey information, elevation models, and LandSat TM landcover, a GIS modeling framework was constructed to map agroecological regions where Golden Harvest's suite of corn hybrids were bested adapted in the western Corn Belt. In addition, a geospatial framework was developed to identify the soil landscapes that had the best soil qualities and root zone water-holding capacities, reducing risks to drought events. A toolkit of ESRI ArcView extensions were developed for on-screen digitizing of seed production fields, acreage calculations relative to soil properties, and documenting fields for growers and isolation distances.

INTRODUCTION

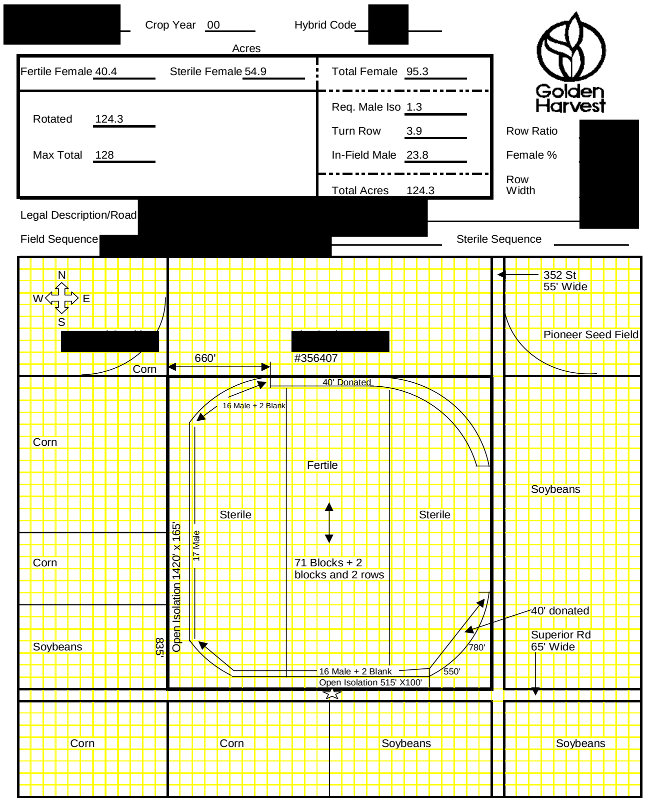
Although seed companies collect extensive information of corn hybrid performance from seed production fields and strip trials over broad geographic regions, the integration of imagery, digital soil survey and climate databases, agriculture infrastructure data, and genotypic characteristics in a geospatial context is still a newly emerging research and application model. Each year in the Corn Belt, seed companies contract with growers to produce seed and also develop a network of strip trials to evaluate the performance of commercial corn hybrids. Similarly, university researchers also conduct strip trials across multiple environments to evaluate commercial hybrids.

Seed corn production fields are managed to maximize yield, while maintaining purity and quality. Apart from applying best management practices, seed corn production can be maximized by simply better planning and layout of the production fields. More efficiently planned production fields rely on the ability to accurately quantify field "elements" (a field element, in this case, referring to whether that particular segment of the field contains turn rows, male isolation, fertile female, and sterile female). A secondary benefit of being able to accurately plan and quantify a field's potential production (all other effects such as weather and management practice, being equal), is the ability to match production needs to market demands.

Geographic information systems are needed in the seed industry to provide key company decision-makers with timely geospatial information of field layout (inbred or hybrid location), isolation distances, biophysical constraints of the fields, accurate estimates of the next growing season's seed production in advance, and an image-based approach to tracking yields on the landscape. Such resources can also be used to locate trial sites to insure that spatial extrapolation domains for specific hybrids have been adequately defined. Geospatial information on soils, climate, and hybrid performance therefore provides the necessary framework for evaluating "genotype x environment" interactions at varying scales, from the field to local growing regions and multi-state marketing regions.

Previous Mapping Practice

The J.C. Robinson Seed Company of Waterloo, Nebraska, which markets Golden Harvest brand products, outlined a series of issues within their business model to improve acreage estimates of seed production fields and the geospatial analysis of yield on strip trials, using their commercial corn hybrids. The J.C. Robinson Seed Company production managers and agronomists relied upon Microsoft EXCEL and PAINT to track and map seed production field units. The methodology for mapping fields lacked a backdrop image of the field and did not integrate other datasets related to soils or road networks. The mapping approach did not create a georeferenced database that was portable to other geographic information systems. Moreover, the resulting production maps could not readily aid the field staff in pre-season planning and decision- making, as the production maps were often constructed *after* planting. The past mapping process relied upon hand-drawn accounts of features estimated on a grid by field supervisors. This pre-map was used as a guide for field technicians to later capture field boundaries through a non-differentially corrected global positioning system (GPS) receiver. The field boundaries were later downloaded and manually corrected in a "paint" type program, commonly associated with graphics packages. Figure 1 illustrates the typical map file from a seed production site that was generated under the past management approach described above.



[redacted] Crop Year 00 Hybrid Code [redacted]

Acres

Fertile Female 40.4
Sterile Female 54.9
Total Female 95.3
Rotated 124.3
Max Total 128
Req. Male Iso 1.3
Turn Row 3.9
In-Field Male 23.8
Total Acres 124.3
Row Ratio [redacted]
Female %
Row Width
Legal Description/Road [redacted]
Field Sequence [redacted]
Sterile Sequence

Figure 1. Elements of the grower's map for The J.C. Robinson Seed Company (Golden Harvest brand).

Hybrid/inbred evaluation and seed production by The J.C. Robinson Seed Company relies upon multiple seed production areas in eastern Nebraska. The mapping and documentation of fields represents a significant commitment in time and labor. The data resulting from such trials was difficult to synthesize across sites and link to site-specific information from other geospatial databases, such as soil surveys or weather stations. The previous mapping approach demanded considerable fieldwork from technicians, but these steps failed to provide the value-added information needed for accurate measurement of planted acres and ensuring proper isolation of seed production. Proper isolation is a significant geospatial issue and relates to the occurrence of different hybrids in close proximity that could be contaminated by foreign pollen sources.

A geospatial digitizing tool was needed to map isolation rows and distances, turn spaces, and capture features known to influence seed production.

Objectives

The objectives of our work in this geospatial decision support system were to: 1) develop a series of tools in ArcView that allow on-screen digitizing, attributing, and spatial analysis of seed production and strip trial fields using digital orthophotography and soil survey geographic databases, 2) develop new soil interpretations that would guide selection of fields and provide a quantitative approach to explanation of yield, and 3) develop a framework for the geospatial and temporal analysis of yield for seed production and strip trial fields.

MATERIALS AND METHODS

Mapping Seed Production Field Elements

ArcView (Version 3.2, ESRI, 2000) was used to as the primary geographic information system for on-screen digitizing and digital capture of seed production and strip trial fields. An accurately mapped seed production field provided the basis for field management decisions throughout the growing season.

Data Integration

USGS Digital Orthophoto Quadrangles (DOQ; Nebraska Dept. of Natural Resources, 2001), the Public Land Survey System (http://dnr.state.ne.us/) and the USDA/NRCS Soil Survey Geographic Database (SSURGO; Soil Survey Staff, 1995) were integrated to evaluate the soil productivity and identify constraints to yield, and georeferencing of fields relative to weather stations. These GIS layers provided decision support through assessment and selection of potential seed production fields and for deriving new parameters for the analysis of yield. The SSURGO database provides seedsmen with more than a hundred soil properties and interpretations that can relate to agronomic production. Collectively, datasets provided a georeferenced platform upon which various GIS-based analysis tools were constructed. For the field digitizing tool, the DOQs provided an excellent backdrop upon which production managers could outline fields and capture field elements without visiting the field. The PLSS data provided the base data for an automated zoom tool as part of the field digitizer extension and represented an attribute already common within the seed company databases.

Geographic Setting

For this study, the seed production fields were located in eastern Nebraska (Figure 2), primarily associated with Polk, Butler, Seward, and Saunders Counties. These counties occur on the western edge of the Corn Belt, along the major ecological boundary defining the rainfed and irrigated regions. All seed production fields have irrigation systems, but strip trials commonly occur under rainfed conditions. This suite of counties represents part of the East District of Nebraska for agricultural statistics and generally leads the state in all corn production categories (http:/www.agr.state.us/agstats/index.htm; Nebraska Agricultural Statistics Service, 2000). This seed corn production region is dominantly classified as a Typic Udic soil moisture regime, which suggests that in most years, growing season moisture is adequate for plant growth.

This region varies by only 300 heat units (growing degree-days), but these counties differ by about 100 mm (4 in) in mean annual water balance. Between Seward and the David City weather station, there is a distinct difference in soil-climate characteristics, with the David City location having nearly a two-week advantage in the cumulative number of days that the soil profile remains moist during the growing season. The differences in biological windows at 5^{o}C can relate to subtle distinctions in late season water supply during grain-fill, as well as nitrogen-mineralization and microbial activity from planting to emergence.

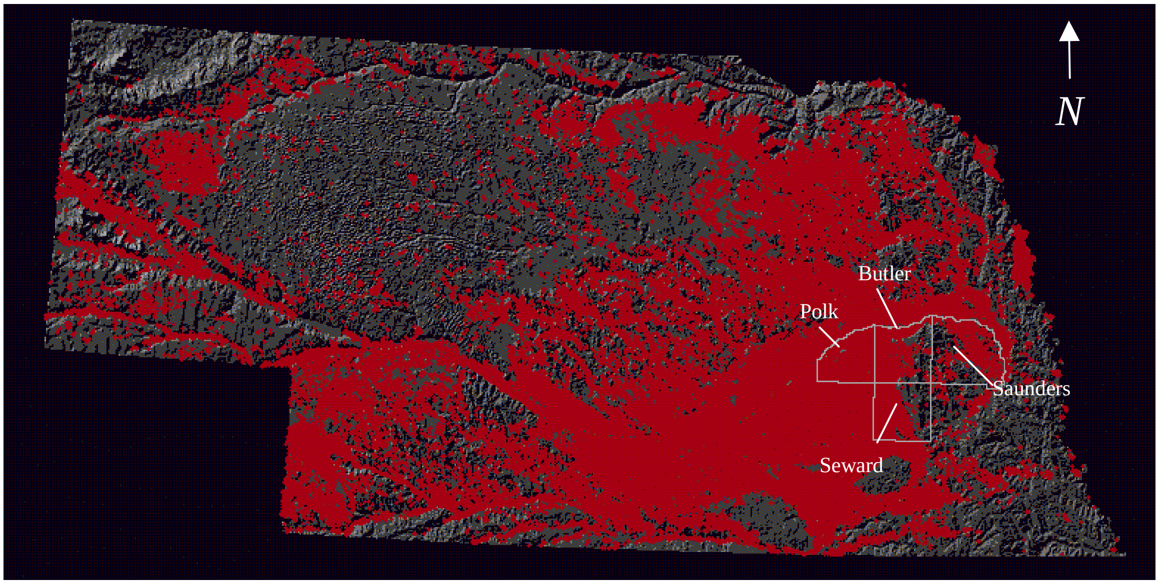


Figure 2. Shaded relief of Nebraska illustrating the distribution of irrigation (red) and the location of the seed production fields.

Table 1. Summary of weather stations for the four county growing region, based upon 1961 to 1990 normals.

Station Name	MAP	PET	AWB	MSWB	GDD	FFP	STR	SMR	BIO5	BIO8
	-----------(mm)------------				(50°F)	(32°F)			(d)	(d)
Ashland 3N	753	712	41	-137	3346	161	Mesic	Typic Udic	218	206
David City	758	703	54	-147	3412	167	Mesic	Typic Udic	205	202
Fremont	773	725	48	-145	3506	159	Mesic	Typic Udic	216	210
Mead ARDC*	695	704	-9	-159	3468	156	Mesic	Typic Udic	215	203
Seward	691	734	-43	-180	3614	173	Mesic	Typic Udic	205	212
Wahoo	887	697	190	-101	3286	155	Mesic	Typic Udic	214	202

*Period of record was 1969-1990.

MAP = Mean Annual Precipitation
PET = Potential Evapotranspiration
AWB = Annual Water Balance (MAP – PET)
MSWB = Mean Summer Water Balance (MAP – PET)$_{\text{jun-jul-aug}}$
GDD = Growing Degree-Days, base 50 °F

STR = Soil Temperature Regime
SMR = Soil Moisture Regime
BIO5 = Biological Window at 5 °C
BIO8 = Biological Window at 8 °C
FFP = Frost-Free Period, base 32 °F

Note: The Wahoo weather station represents an anomaly in precipitation and growing degree-days with respect to the other stations in the growing region.

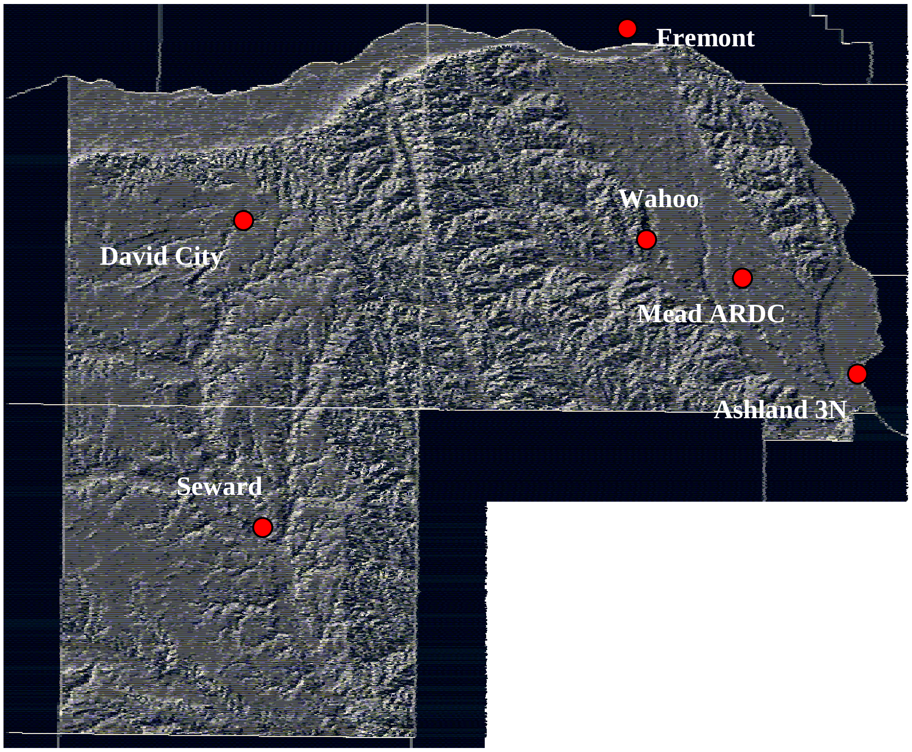


Figure 3. Location of long-term weather stations relative to physiography in the seed production region.

RESULTS AND DISCUSSION

GIS-Based Production Field Mapping

The outcomes of this project addressed the following goals of The J.C. Robinson Seed Company:

- Better field planning capabilities and orchestration of field events.
- More accurate estimations of planted acres delivered in a timely (pre-planting season) manner that build confidence with growers.
- Reduction of fieldwork component for collecting GPS coordinates and field elements.
- Enhanced data collection processes, and corresponding enhancement in field information management techniques.
- Builds a decision support system that integrates the components and factors of yield and develops that analytical tools for explaining "Genotype x Environment" interactions.

A Geographic Information System (GIS) in the form of ESRI's ArcView software provided the basis for the new mapping tools. ArcView includes a process for customization of the both the GIS operation and GUI (graphical user interface) enabling the system to be tailored to the specific needs of a user. Despite the fact that ArcView has many standard editing functions built-in, only advanced users may extract the full benefit of the standard ArcView system.

Step 1:

The customized ArcView extension incorporated a number features designed to fill the needs of The J.C. Robinson Seed Company production unit. High resolution ortho-rectified satellite and aerial photography can be used as a backdrop to the main field planning window. Before production field delineation begins, the user is presented with an interface to enter field attributes (Figure 4).

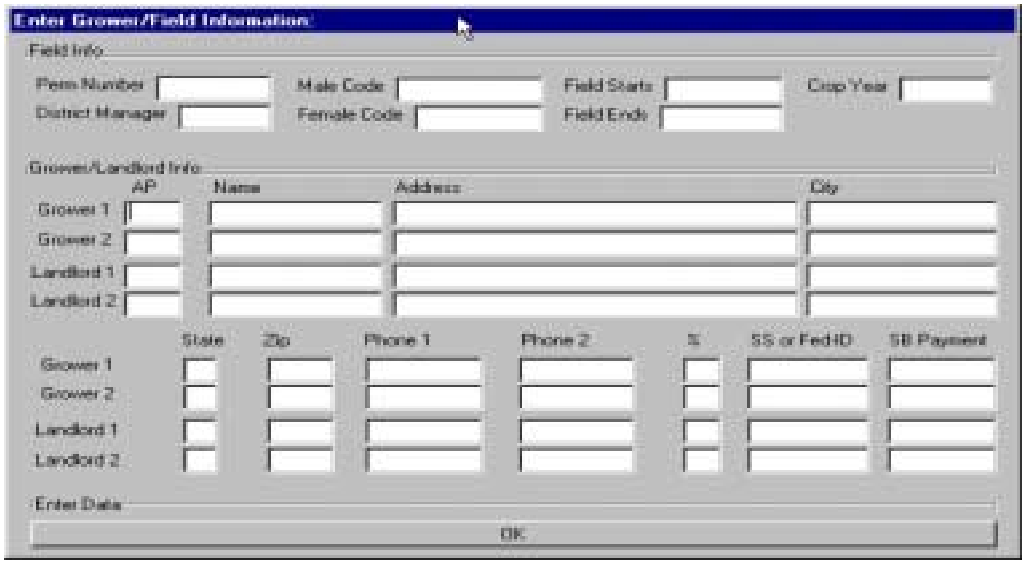


Figure 4. Field data entry window in ArcView, illustrating data elements for the grower.

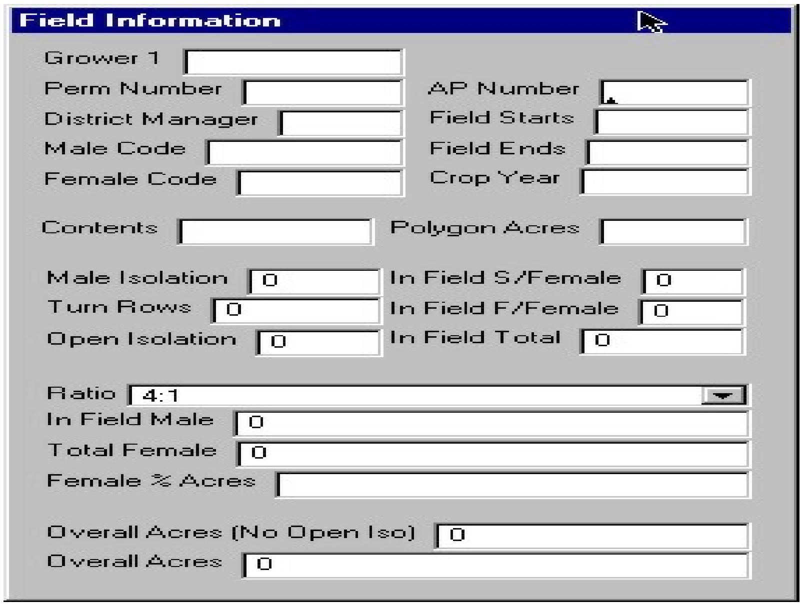
Step 2:

These data are collected for the user, and stored in ArcView for future use in the automated mapping procedure. Once the user has entered relevant field information (field number, grower's address) the user is presented with the standard mapping interface (Figure 5).

Figure 5. Standard interface presented to the production field planner. Note the simplified interface utilizing only a few buttons and tools. Also, note the DOQQ as a backdrop and the inferences of soil erosion and organic matter content that can provide context for interpreting yield.

Step 3:

Once the user begins digitizing the field boundary, an information window appears on the screen, which displays field information and element (i.e. turn row, open isolation) acreage information in *real-time*. That is, as the user adds field elements, or changes the boundary positions of those elements, the information concerning calculated acres will be updated on-the-fly (Figure 6). From the DOQQ, the technical agronomist can recognize and map eroded areas, saline seeps, small depressions that pond in the spring, weed patches, hail damage, areas of insect infestation, or areas of plant diseases and nutrient deficiencies. The DOQQ often provides sufficient landscape context for delineating these impacts on fields, without the need to GPS individual spots. Similarly, soil test locations and results can be added to these fields as *ad hoc* symbols, following conventions in soil surveys.



Field Information

Grower 1			
Perm Number		AP Number	
District Manager		Field Starts	
Male Code		Field Ends	
Female Code		Crop Year	
Contents		Polygon Acres	
Male Isolation	0	In Field S/Female	0
Turn Rows	0	In Field F/Female	0
Open Isolation	0	In Field Total	0

Ratio	4:1
In Field Male	0
Total Female	0
Female % Acres	
Overall Acres (No Open Iso)	0
Overall Acres	0

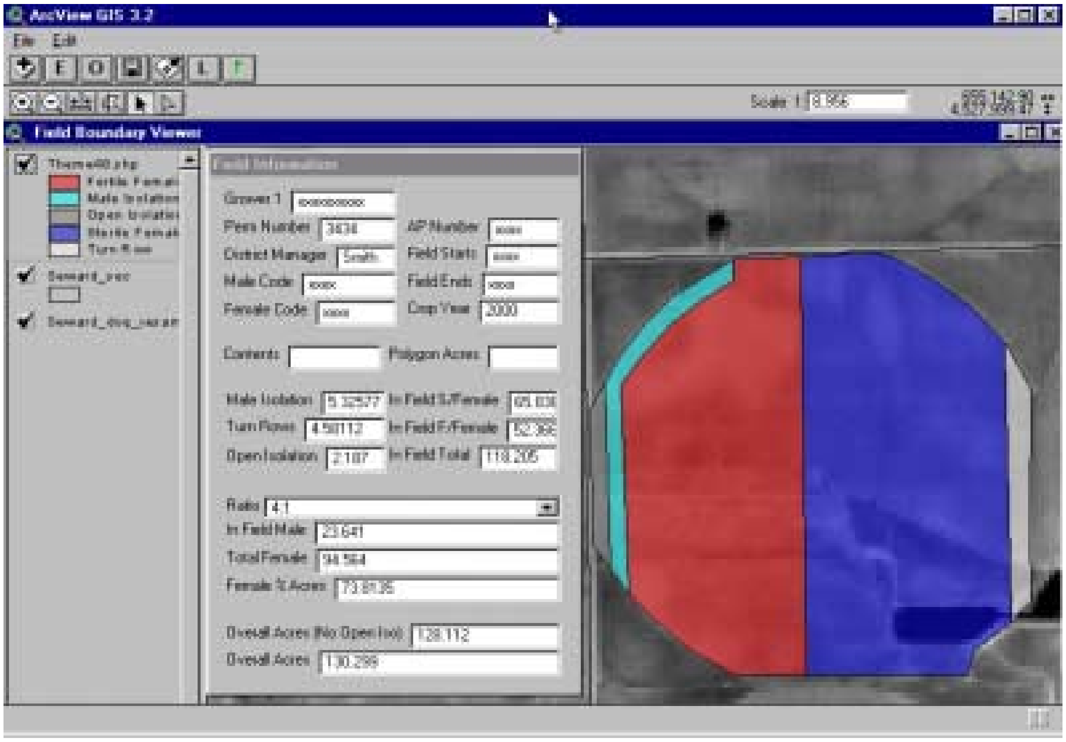
Figure 6. The field information form. These forms are updated and calculated on-the-fly as the user enters and manipulates the field element boundaries.

Step 4:

The user begins delineating the field boundary, then filling-in each field element using the custom drafting tools (Figure 7). The user may query metrics for the field elements, such as measuring acres of fertile female, isolation distances, and other setbacks. This information is later used to calculate potential seed yield. This GIS approach removes the necessity for fieldwork, and allows the production management to spend off-season time to plan production fields for the next growing season and reanalyzing the past year's yield. A final step made available to production staff is the ability to easily print out farm field plans not only for in-house use, but also for grower's and custom applicators as well.

Step 5:

The user can create an ArcView layout as a template with this field information on a single 8.5 x 11-inch sheet (Figure 8). Although these maps are generated for field tracking and overall documentation, these maps are also provided to contractors for detasseling and custom application.



Grower 1 xxxxxxxxxx
Pers Number 3434
AP Number xxxx
District Manager Smith
Field Starts xxxx
Male Code xxxx
Field Ends xxxx
Female Code xxxx
Crop Year 2000
Contents
Polygon Acres
Male Isolation 5.32577
In Field S/Female 65.03
Turn Rows 4.50112
In Field F/Female 52.36
Open Isolation 2.187
In Field Total 118.205
Ratio 4:1
In Field Male 23.641
Total Female 94.564
Female % Acres 73.8136
Overall Acres (No Open Iso) 128.112
Overall Acres 130.299

Figure 7. The field delineation process captures grower information. Note the on-the-fly calculation of field parameters important to maximizing seed production of the field.

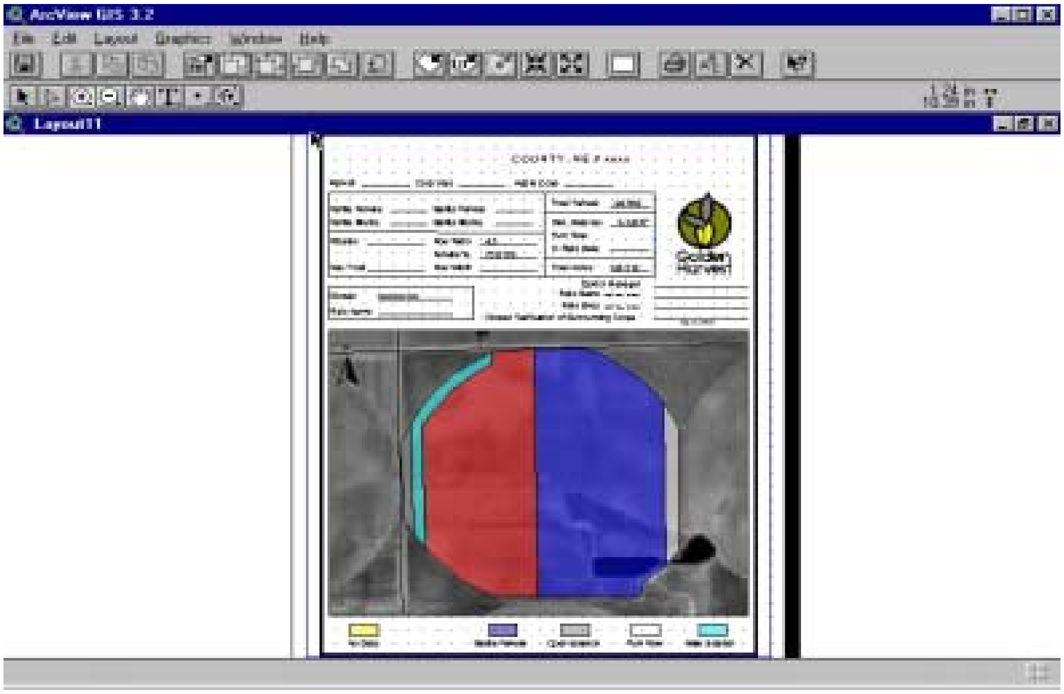


Figure 8: Automatic layout generation for printing hardcopy for the field and grower's records. The layout creation process has been reduced to a single button press, and customized code extracts the information and positions it on the layout. Hardcopy generation is still an important process for farm record keeping, as well as documentation for field staff to edit and note localized field problems.

Geospatial Analysis of Growers and Fields

Using the GIS overlays as shown in Figure 8, the root zone water-holding capacity (RZWHC) and soil rating for plant growth (Sinclair et al., 1999) were summarized across the fertile female blocks. A weighted-average calculation was derived for each SSURGO mapunit, field, and grower, which were later used as parameters in a simple empirical yield model. The root zone water-holding capacity reflects the total “plant available” water storage across an effective rooting depth in soils (Sinclair et al., 1999; Soil Survey Staff, 2000). For seed production, this soil interpretation identifies the “buffering capacity” of a soil to resist drought events. In general, soils with higher root zone water-holding capacities will require less supplemental irrigation and offer an inherent mitigation against drought. Additionally, the soils with higher root zone water-holding capacities will have better nutrient retention characteristics, which are key soil qualities, given a more uncertain climate.

The Soil Rating for Plant Growth (SRPG) reflects the integration of twenty-five physical, chemical, mineralogical, and landscape properties of soils (Soil Survey Staff, 2000). In this rating scheme, the index values range from 0 to 100, with 100 representing the highest soil productivity or combination of soil, climate, and landscape traits. The SRPG calculations followed the “Storie Index Soil Rating” (Storie and Weir, 1958; Storie, 1978), which was based on soil characteristics that govern the land’s potential utilization and productive capacity. The underlying assumptions of the SRPG strongly reflect the soil and environmental growing conditions for maize. The RZWHC and SRPG represent coupled parameters or metrics from the SSURGO database that strongly correlate to corn yield (Gadem, 2000).

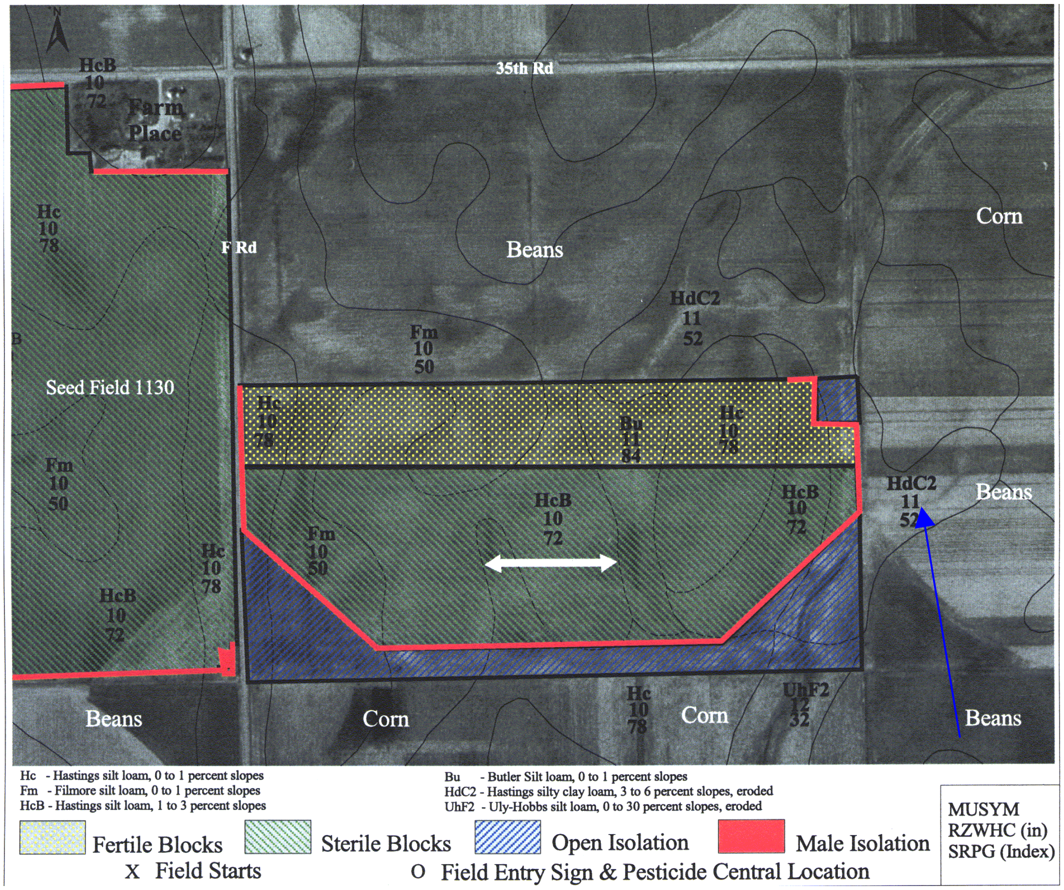


Figure 9. ArcView layout of J.C. Robinson seed field in Seward County, Nebraska. The MUSYM is the SSURGO map unit symbol, RZWHC is the Root Zone Water-Holding Capacity of each SSURGO map unit, and SRPG is the Soil Rating for Plant Growth (Soil Survey Staff, 2000). The backdrop is the USGS digital orthophotograph with the SSURGO vectors superimposed.

Yield Modeling and Interpretation

The digital maps of the seed production fields enable introduction of soil parameters into empirical corn yield models. As part of the attribute data collected for each field, the planting date, management score, relative maturity of the hybrid or inbred, crop rotation, SRPG, RZWHC, percent green-snap, terrain variables (elevation, slope, and aspect), and climatic parameters from the nearest weather station to the field, can be used as predictors of corn yield. Although soil surveys provide a long-term estimate of corn yields by SSURGO mapunit, the SSURGO yield value lacks the temporal variability associated with climatic events, such as drought.

The linkage between fields, soil properties, landscape characteristics, traits of the hybrid, and the nearest weather station can be used to derive "in-house" empirical relationships that explain a significant portion the yield. Similarly, this framework can be expanded to include other factors such as weed populations and insect damage, and scouting information as it becomes available. In addition to the seed production yield modeling, there is also the need for simple empirical relationships of yield on a county basis to project yield behavior and potential climatic or environmental risks. For example, Figure 10 presents the corn yield profile for Butler County, Nebraska, under irrigated and non-irrigated conditions (USDA/NASS, 2001). These relationships can be derived for each county and used to map areas of higher yield variation or where regions share similar yield behavior to El Nino/La Nina events through time. Figure 10 illustrates the linear trend of increasing yields through time for both irrigated and non-irrigated yields and the dampened yield variation under irrigation. The progression in yield is attributed to improvement of corn hybrid genetics and cultural practices (tillage and pest management; soil fertility management).

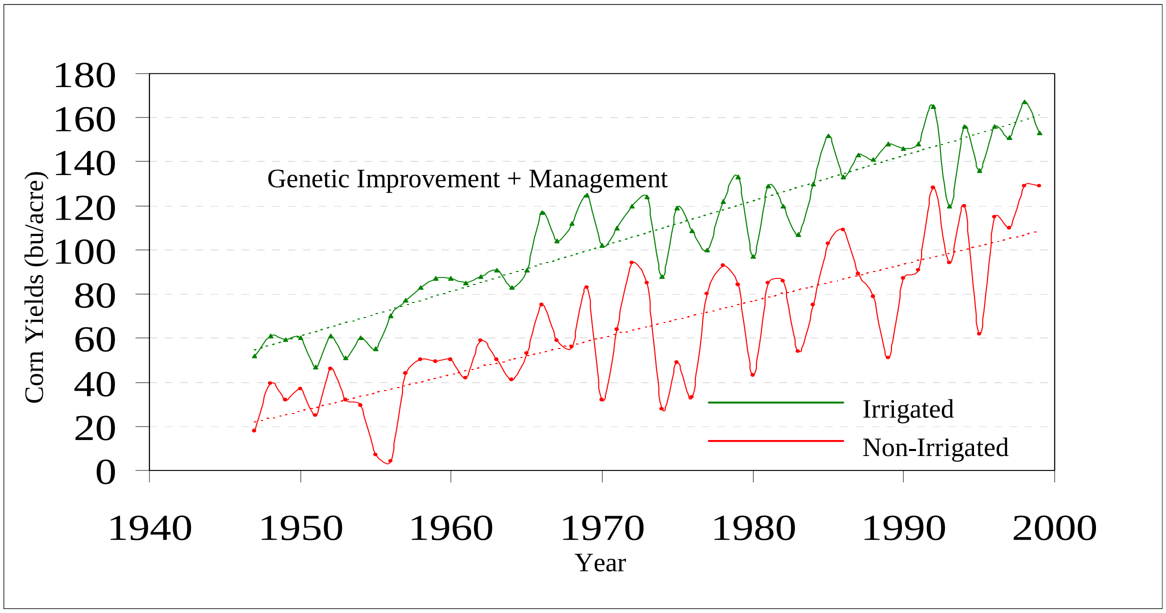


Figure 10. Comparison of irrigated and non-irrigated yields through time for Butler County, Nebraska. The major drops in non-irrigated yields are dominantly associated with major drought events during 1956-1957, 1974-1976, 1980, and 1988-1989. However, not all counties in the conterminous U.S. will show this progression of yield through time.

In decision support, geospatial "rules of thumb" can be developed from seed and strip trial yield histories to better understand hybrid or inbred behavior and predict potential yields prior to actual harvest. Figure 11 shows a simple empirical relationship between yield and planting date. Similar relationships can be developed for growing season precipitation and heat units to identify impacts of climatic variability on closely clustered seed production fields. These relationships will have geospatial constraints to their applicability. As Figure 12 illustrates, the field locations or clusters can also be summarized by more regional representations of climatic parameters to identify different production zones or agroecozones (Follett, 1996; Waltman et al., 1999). Strip trials of commercial seed products can be targeted for specific

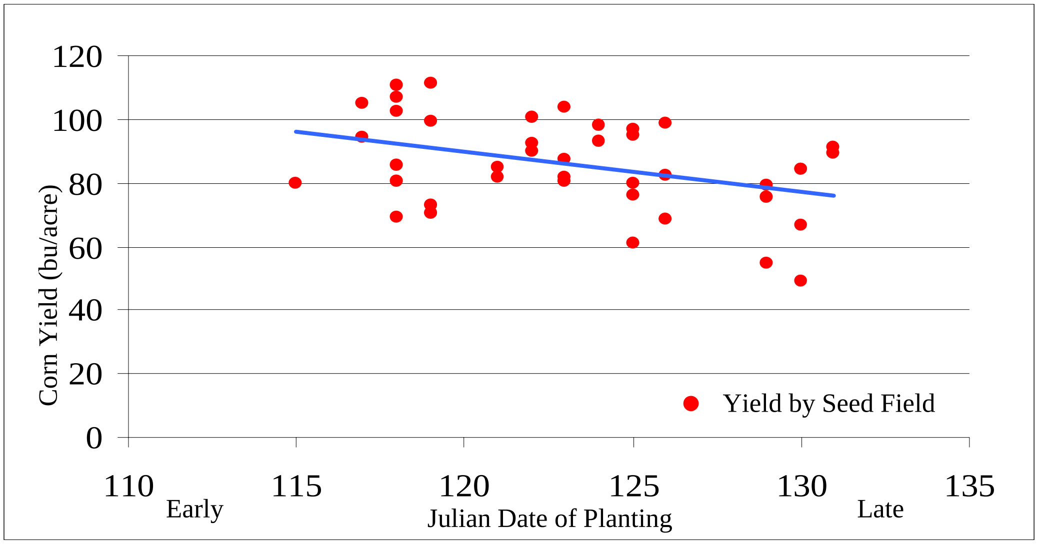


Figure 11. Relationship between corn yield and planting date for seed production fields during 2000. The graph indicates an important "rule of thumb" that early planting in late April generally produces higher yields. These "rules of thumb" can serve as working recommendations to growers within an geographic inference space.

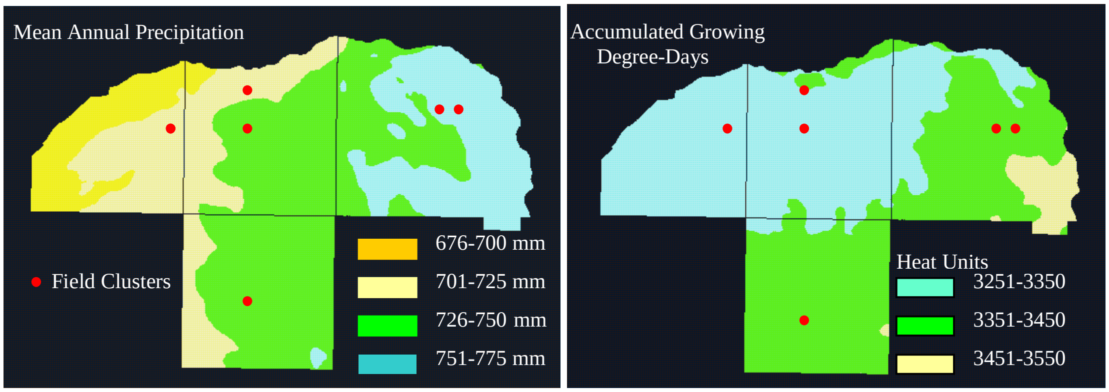


Figure 12. Generalized location of seed production fields relative to regional precipitation and growing degree-days. Climatic parameters were mapped from regression equations derived from a population of weather stations and applied to USGS digital elevation models. The mean annual precipitation and growing degree-day maps were based on 1961 to 1990 normals.

environments. Climatic interpretations can be coupled to derive "growing regions" that define landscapes sharing similar agronomic behavior. This approach can also be extended to cluster farms or growers that should share a similar yield response through time.

SUMMARY AND CONCLUSIONS

A geospatial decision support framework was developed for seed production and strip trial fields of The J.C. Robinson Seed Company. The capture and attributing (yield, management score, planting date, type and relative maturity of the hybrid/inbred) of fields, coupled with digital orthophotographs and SSURGO data provides a geospatial infrastructure to support seed production, technical agronomic support, research and development, as well as marketing and sales of commercial seeds. ArcView 3.2 along with developed extensions for on-screen digitizing of fields and collection of grower information were constructed and tested within the business model of J.C. Robinson Seed Company. The field digitizing tool will enter The J.C. Robinson Seed Company production system in the first quarter of 2001 for implementation and testing. Production staff will provide valuable feedback on the tools and operations, allowing the programming team to make adjustments to the Graphical User Interface (GUI). Future directions will include modules for "Genotype x Environment" (GxE) interactions and expanded analysis of multi-environment field trials. Our current approach integrates imagery, soils, climate, and terrain data bases across multiple scales and years of yield analysis. Several prototype GxE tools have been created and are currently being tested by staff within the research and development departments of major seed companies. GIS-based GxE tools will provide seed companies with the ability to visualize yield data and extract meaningful environmental relationships with geospatial databases of soils, terrain, and climate.

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