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PRECISION AGRICULTURE: A TOOL FOR COTMAN

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Abstract

The determination of field sampling locations for COTMAN software is a highly subjective process. COTMAN provides guidelines for sampling with respect to practices and numbers. Many producers do not adhere to the guidelines because of the associated time and logistical requirements. In fields with significant developmental variability, sampling locations that merely represent an average condition of the field fail to address the specific management needs of different regions of the field. In fields with little variability, the general condition of the field can be assessed by a small number of well selected sampling locations. Research was conducted at Texas A&M University (TAMU) in 2003 to explore the utility of using precision farming technologies to assess variability, select sampling locations and monitor plant development throughout the growing season. Test sites which consisted of production irrigated and dryland fields in south and south-central Texas were monitored throughout the growing season by COTMAN and a TAMU developed plant height mapping system called HMAP. Two sampling locations selected from consistently average height regions within a field were able to generate equivalent COTMAN outputs to those generated with three times as many sampling locations from the same field for all sites considered in this study, irrespective of field size.

Introduction

The utility of COTMAN is maximized when accurate output information can be obtained from minimal inputs. Management zones which reflect actual field conditions and desired management scheme must be selected in order to ensure meaningful output from the software. Precision agriculture technologies can aid in assessing field conditions and in determining management zones.

Selecting the best COTMAN sampling scheme for a particular field requires knowledge of a wide variety of factors associated with cotton production, field conditions and management techniques of the producer. In a field scale management scheme, the entire field is managed as a single unit and the desired output of COTMAN is management recommendations that reflect the general condition of the field. When cotton is managed on a sub-field or site specific basis, each field is divided into unique management zones that share similar characteristics and the desired output of COTMAN becomes management recommendations for each zone. In fields with limited variability, site specific management practices become unnecessary provided the COTMAN observation sites were well selected.

In a site specific management scheme, it is necessary to assess the amount of developmental variability within a field. A variety of tools are available to assess in-field variability. Some commonly available tools include yield maps, aerial imagery, and soil maps. Other tools such as remotely sensed NIR (near infrared) imagery or the HMAP system offer alternative methods for assessing variability within a growing season. The standard deviation of yield or plant height is one measure of the level of variability present. The Normalized Difference Vegetation Index (NDVI) calculated from NIR and RGB (Red, Green, Blue) multi-spectral imagery is an example of another. Aerial photographs collected during bare soil conditions can be used to identify variable soil conditions within a field. While not always definitive, aerial photographs that show significant color variation across the field are often indicative of variable growing conditions within the field.

End-of-season data and in-season data are both valuable tools for determining management regions and sampling locations for COTMAN. In-season data provides added utility as well through the development of custom tailored management strategies pertaining to the actual growing conditions and crop development trends during the growing season. NIR imagery makes it possible to develop maps of NDVI; a parameter associated with vegetative vigor within a field. The HMAP system generates plant height maps which can be combined with historical height maps to calculate rate of growth; another parameter associated with vegetative vigor. These parameters related to vegetative vigor make it possible to identify and spatially locate regions of the field that exhibit abnormal development characteristics and unique management needs.

The tools of precision agriculture make it possible to identify extremely small regions with unique management needs; however, it is not always practical or efficient to manage each region independently. It is therefore important to select management zones that both represent unique conditions within a field, and cover enough area in an accessible location such that site specific management is feasible. COTMAN management zones are normally several acres in size because the intensive crop scouting requirements make it prohibitive to consider small zones. A one acre odd shaped region in the middle of a 100 acre field with straight rows is an example of a non-feasible COTMAN management zone while it would be feasible for other precision agriculture applications such as variable rate chemical or fertilizer application.

Once COTMAN management zones have been determined, it is necessary to select a sampling scheme that will adequately assess the general condition of each zone. COTMAN recommends four sampling locations for each zone of 40 acres or less and an additional sampling location for each additional 10 acres. This paper will present methodologies for selecting efficient sampling schemes through the use of precision agriculture tools and a Geographic Information System (GIS).

Methodology

Test locations were selected from two distinct Texas growing regions with intense cotton production. One location is part of the Texas A&M University IMPACT Center located in Burleson County (Brazos River valley of south-central Texas). Irrigated and dryland sites with 30 inch row spacing were originally included from this location; however, poor establishment on the dryland site due to unseasonably dry conditions after planting caused it to be unusable. The irrigated site uses a conventional center pivot irrigation system and rows are oriented radially around the pivot and managed with conventional tillage. The other location is in Wharton County on the coastal plains of south Texas. Irrigated and dryland sites with 40 inch row spacing were utilized at this location. The Wharton County irrigated site uses a conventional center pivot irrigation system coupled with furrow irrigation in corners. Straight rows and conventional tillage are used on both the irrigated and dryland fields.

Four sampling locations were chosen at each site by an experienced COTMAN scout. Two additional sampling locations were selected from the aerial imagery of each field in Digital Orthophoto Quarter Quad (DOQQ) format obtained from the Texas Natural Resource Information System (TNRIS) database. The additional locations were selected by identifying soil color areas not represented by the scout selected locations. The latitude and longitude of each sampling location was recorded with a differentially corrected Global Positioning System (GPS) receiver, and those same sites were monitored with COTMAN for the entire growing season. Figure I shows the COTMAN sampling locations at the IMPACT Center and the DOQQ of the site.

Each field was monitored per COTMAN recommendations throughout the growing season. The monitoring sites were located by scouts for sampling via handheld differentially corrected GPS receivers. GPS was utilized to ensure that exactly the same locations were monitored each time data was collected. It also made it possible for different scouts to monitor the same fields in a consistent manner.

Plant height was spatially recorded at each test field on an approximately bi-weekly basis throughout the growing season using the HMAP system. HMAP utilized a tractor based platform until the cotton began to touch the axles and then was transferred onto a high clearance sprayer. Height was measured across two rows on the 40 inch sites and across 4 rows on the 30 inch site; the difference is attributed to implement configuration. Previous research by Searcy and Beck at TAMU verified that HMAP produces comparable results when measuring across 2 rows or 4 rows. Sampling passes were conducted every 60 feet across the field consistent with the boom width of the sprayer and representative of routine field operations in production.

Multi-spectral NIR and RGB imagery was collected throughout the growing season by airplane as weather conditions permitted. Daily cloud cover due to Gulf moisture made it difficult to collect timely high quality aerial imagery in this study; in the 2003 growing season imagery for two dates (July 25 and August 8) was obtained. The aerial imagery which has one meter resolution was collected and georeferenced by a commercial aviation company called GeoVantage. All Burleson County and Wharton County sites were included. The imagery was post processed in GIS to generate maps of NDVI. Equation 1 was used to calculate NDVI. Several measures of NDVI have been suggested in literature; however, this one is most prevalent. Figure II shows NIR imagery and the NDVI map of the IMPACT Center in Burleson County.

1)
$$NDVI = \frac{NIR_{(\mathrm{Re}d)} - RGB_{(\mathrm{Re}d)}}{NIR_{(\mathrm{Re}d)} + RGB_{(\mathrm{Re}d)}}$$

Plant height data, field boundaries, DOQQ imagery, Multi-spectral imagery, and sampling locations were compiled in a GIS for analysis. Figure III shows plant height values recorded at the irrigated fields in both Burleson and Wharton counties with the HMAP system. Each plant height data set was processed to identify the average height of the field and the standard deviation of height across the field. Plant height values within a finite range around the field average were identified for each sampling date. Regions within each field consistently representative of the average plant height were identified. Figure IV shows average height locations and average height regions at the IMPACT center.

COTMAN analysis was conducted for each site in 3 variations: 1) All sampling locations used, 2) Two sampling locations located in consistently average regions used, 3) A single site with greatest variation from average used. The three Nodes Above First Square/Nodes Above White Flower (NAFS/NAWF) development curves for each site were combined onto a single plot for comparison. Figure V shows the NAFS/NAWF plots for the IMPACT center and the irrigated site in Wharton County.

Rate of growth (ROG) maps were generated from the HMAP data for each height sampling field pass. Historical height data was interpolated in the GIS to generate a continuous surface of height across the field. A third degree inverse distance weighted (IDW) surface was used in this interpolation. Rate of growth at each point where height was measured on the subsequent field passes was calculated using equation 2. An example of a ROG map for the IMPACT center is show in Figure VI.

2) $$ROG = \frac{Height_{current} - Height_{historical}}{Time}$$

Results

The test sites located in Wharton County can be classified as fields with little variability. Both the irrigated and dryland fields had a similar and consistent standard deviation of plant height throughout the growing season. The standard deviation of plant height in Wharton County ranged from 3.1 inches for the irrigated field early in the season to 4.6 inches for the dryland field late in the season. Table 1 summarizes the standard deviation of plant height on various dates for the Wharton County and Burleson County Sites. Variations in the field that were expected to be present such as the perimeter of the pivot sprinkler and the area not irrigated are clearly evident in both the HMAP data and aerial imagery. NDVI maps generated from the imagery indicate that that the variation is subtle. Figure III clearly shows the boundary of the center pivot system.

The IMPACT Center in Burleson County is an example of a field with significant variability. Variability at this site is clearly visible in the plant height maps, DOQQ imagery, NIR imagery and NDVI maps. The standard deviation of plant height at the irrigated Burleson County site was significantly higher than either of the Wharton County sites. The standard deviation ranged from 8.6 to 12.1 during the 2003 growing season. In addition, other precision agriculture data available for this site including yield maps, aerial imagery, soil conductivity maps, and soil series maps all indicate significant variability across the field. The Burleson County site would be more accurately managed by COTMAN if divided into smaller management regions. Significant variability is evident in all data sources considered in this study. While the focus of this study was to use the HMAP system in conjunction with COTMAN, data from any precision agriculture data sources would have led to similar conclusions pertaining to variability in this field. Yield maps for both grain and cotton for this field for example also show the same variability exhibited by the data considered in this study.

The NAFS/NAWF curves for all fields show little difference between using 2 sites in consistently average regions versus using all sampling locations. There is somewhat less difference between the two curves in the Wharton County sites (<2 days difference in cutout) where little variability is present across the field compared to the Burleson County site (~5 days difference in cutout) with significant variability. The management recommendations from both SQUAREMAN and BOLLMAN are identical for all fields for both inputs. Conversely, curves generated from a single site with greatest variation from the average were significantly different from the other two at all sites. The difference is greatest for the Burleson County site which is inherently due to the high degree of variability present at the site. COTMAN generates different management recommendations for the Burleson County site using a single site of greatest variability.

ROG maps show the same general variability trends as plant height maps, NDVI maps, yield maps, and aerial imagery. Some negative ROG values are present in all maps generated in this study. The negative values are located in areas of least vigor as identified in the NDVI maps. Less negative values are present when longer time intervals between height measurements are considered. Negative ROG values can be attributed to slow growing plants combined with height measurement error and errors associated with surface interpolation in the GIS. Overall, ROG appears to be a powerful tool to assess vegetative vigor across the field and provides information similar to NDVI.

Conclusions

COTMAN generates uniquely different management recommendations within a particular field when regions of significant variability are considered separately. Variability can be identified through GIS analysis of precision agriculture data collected from the field. Fields with significantly higher standard deviation of plant height than that of fields with little variability might be managed more effectively on a site specific basis. Efficient management zones can be identified within fields of high variability and each zone can be managed in COTMAN as a separate field. COTMAN can be successfully implemented on fields with little variability by conducting crop scouting at significantly less sites than recommended by COTMAN.

Once identified, management zones can be fully characterized for COTMAN with two intelligent sampling locations. Precision agriculture provides a means to select intelligent COTMAN sampling locations within management zones. Intelligent sampling locations selected with the aid of GIS data such as the consistent average height regions identified in this study contain plants representative of the field average. Two sampling locations selected from consistently average height regions within a field were able to generate equivalent COTMAN outputs to those generated with three times as many sampling locations from the same field for all sites considered in this study irrespective of field size.

In this study, rate of growth was calculated by post processing data in a GIS. Regions of vigorous growth as determined by NDVI maps correlate to regions of the highest rate of growth as calculated from HMAP data. Both plant height and rate of growth can be used to identify regions of variability and aid in the selection of COTMAN sampling locations. Continuing research efforts are underway to include a real time ROG calculation in the HMAP system. Real time ROG will undoubtedly offer management opportunities never before considered. Future research in conjunction with agronomists will help determine if ROG can be substituted for or even replace a portion of the crop scouting and plant mapping currently required by COTMAN.

Handheld GPS receivers were a valuable resource in managing this study. The ability to spatially locate the same locations in the field throughout the growing season was both convenient and imperative to maintaining the integrity of the data set. Such technology makes it possible for an 'expert' to make knowledgeable and intelligent decisions on how and where sampling locations are chosen and have confidence that the crop scout in the field will deliver accurate data. All precision agriculture data is related by spatial coordinates (latitude and longitude). If every aspect of an operation is spatially defined, it is then possible to compile the data in a GIS and make intelligent data backed management decisions.

References

University of Arkansas. n.d. Cotton Management Expert System Software. Retrieved December 5, 2003 from http://www.uark.edu/depts/cotman/. Fayetteville, Arkansas.

Plant, R.E., D.S. Monk, B.R. Roberts, R.L. Vargas, D.W. Rains, R.L. Travis, and R.B. Hutcmacher. 1999. Relationships between remotely sensed reflectance data and cotton growth and yield. Transactions of the ASAE. 43(3): 535-546.

Searcy, S. W. and A. D. Beck. 2000. Real-time assessment of cotton plant height. Proceedings of the 5th International Conference on Precision Agriculture, Bloomington, Minnesota, USA, 16-19 July, 2000. American Society of Agronomy, Madison, USA: 2000, publ. 2001. 1-13.

Towson University Center for GIS. n.d. Normalized Difference Vegetative Index. Retrieved January 2, 2004 from http://cgis.towson.edu/. Towson, MD.

Table 1: Standard Deviation of 2003 Plant Height (in.).

Location	Type	05/29/2003	06/10/2003	06/20/2003	07/03/2003	07/09/2003	07/16/2003
Wharton County	Irrigated	3.48	3.10	--	3.45	--	--
	Dryland	4.03	4.67	--	--	--	--
Burleson County	Irrigated	--	--	11.65	--	12.10	8.60

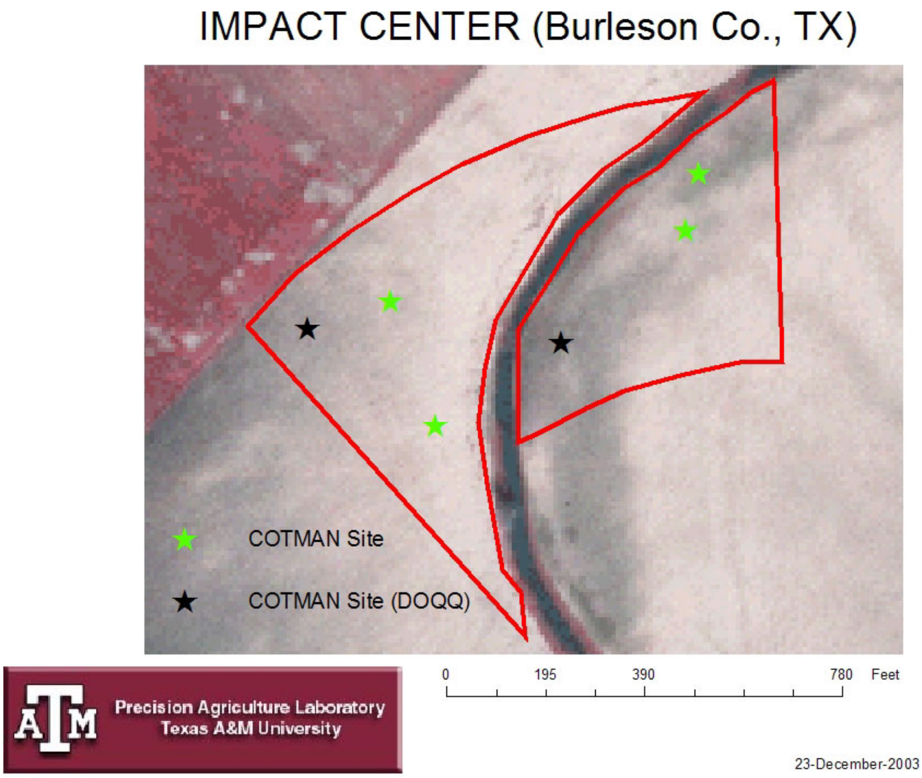


Figure 1: COTMAN Sampling Locations.

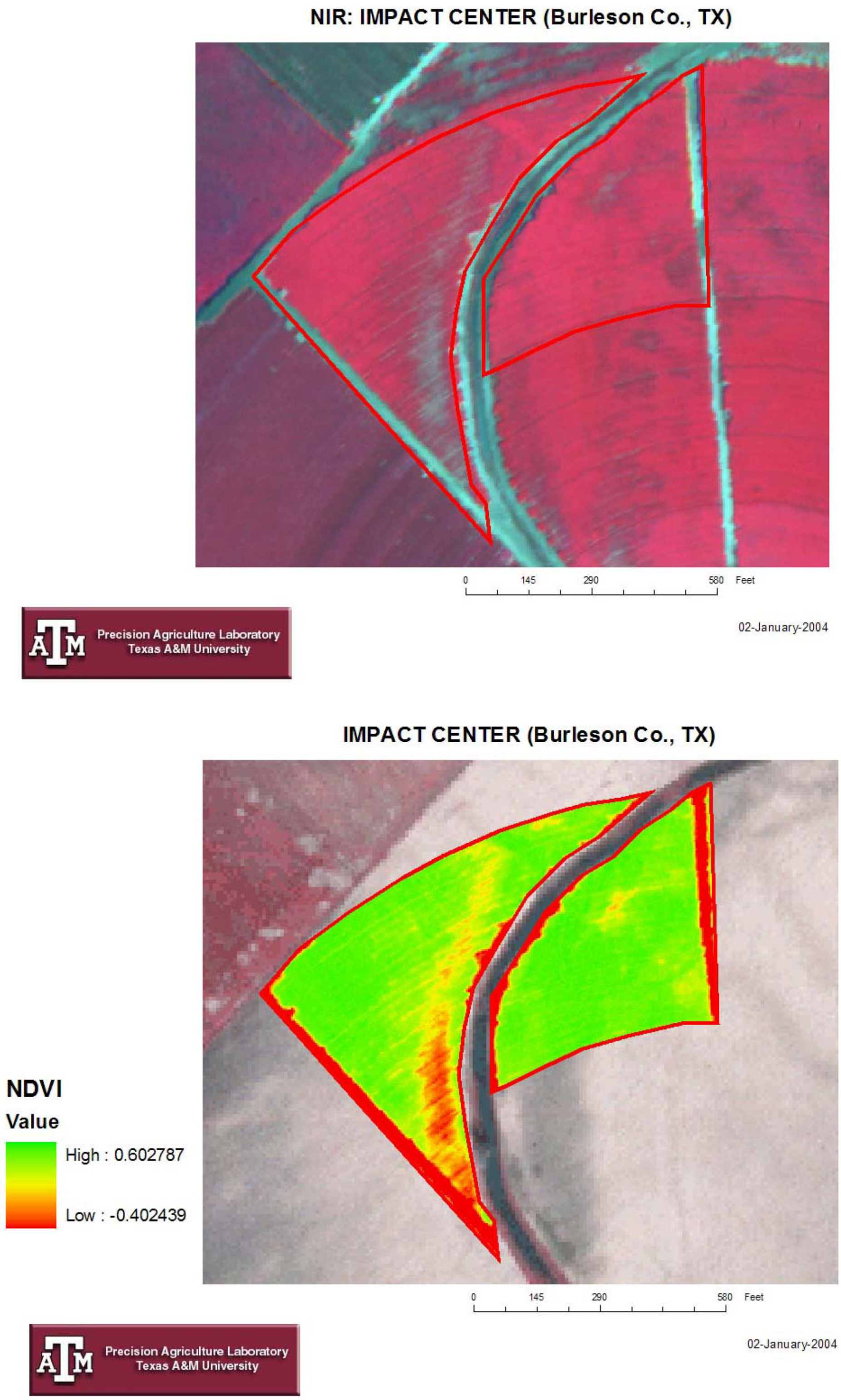


Figure 2: NIR and NDVI Maps (Image Date: July 25, 2003).

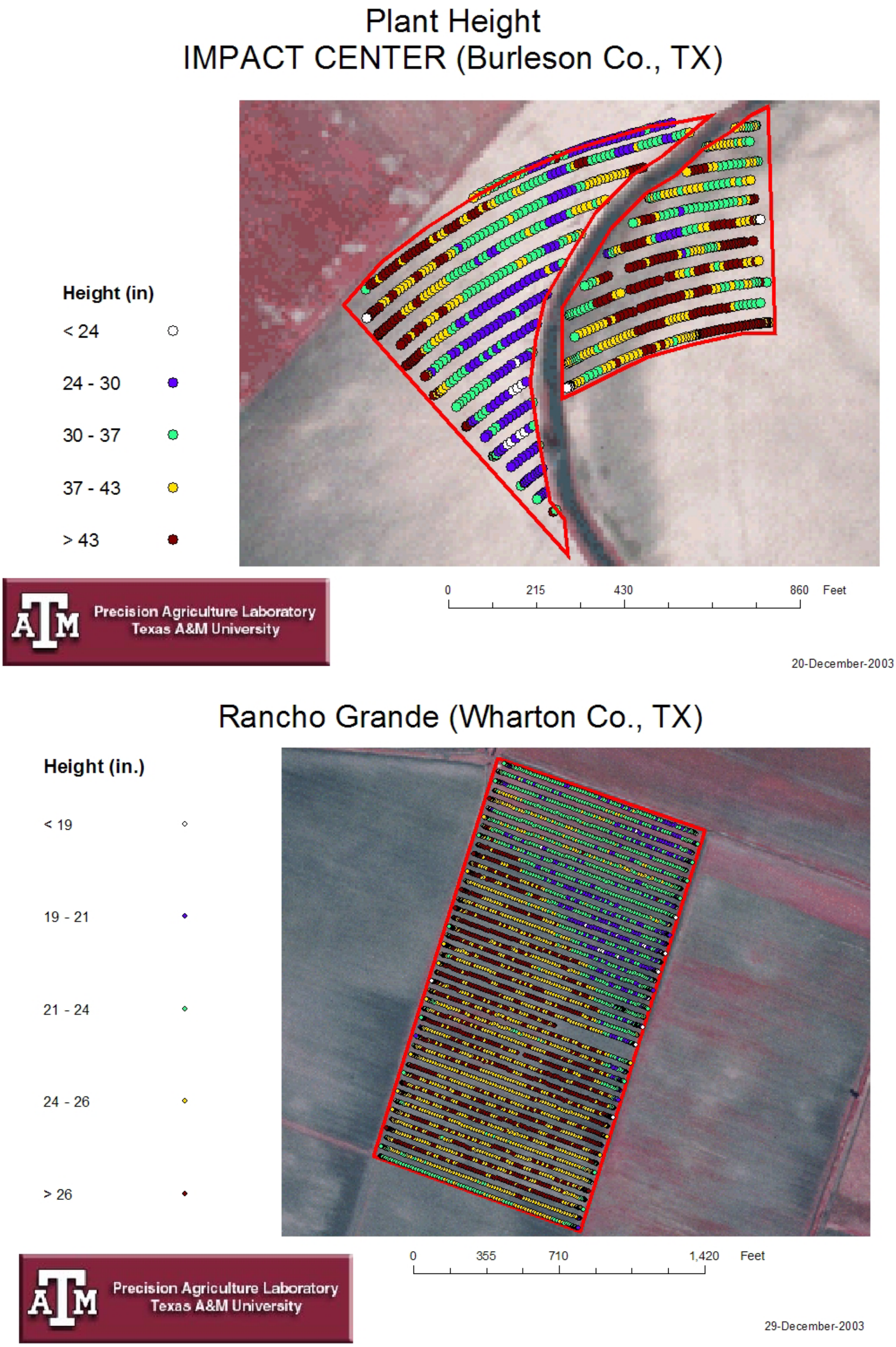


Figure 3: Plant Height Maps Created From HMAP Data.

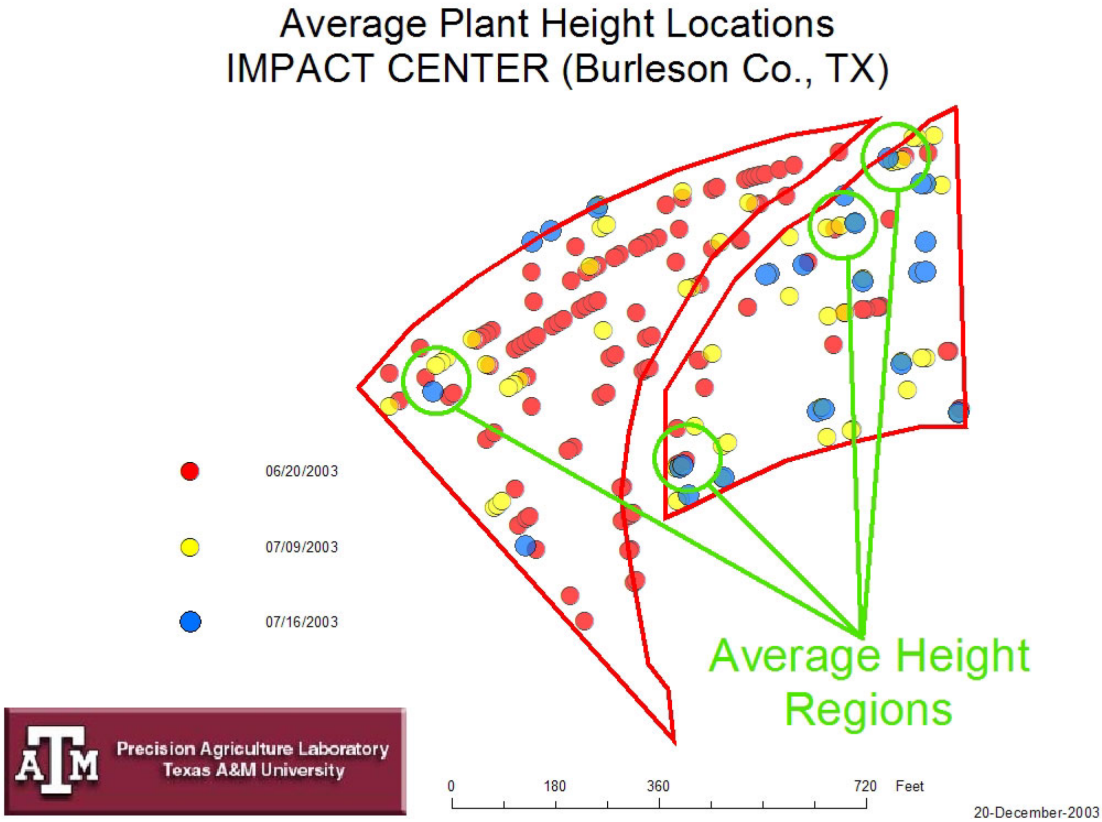
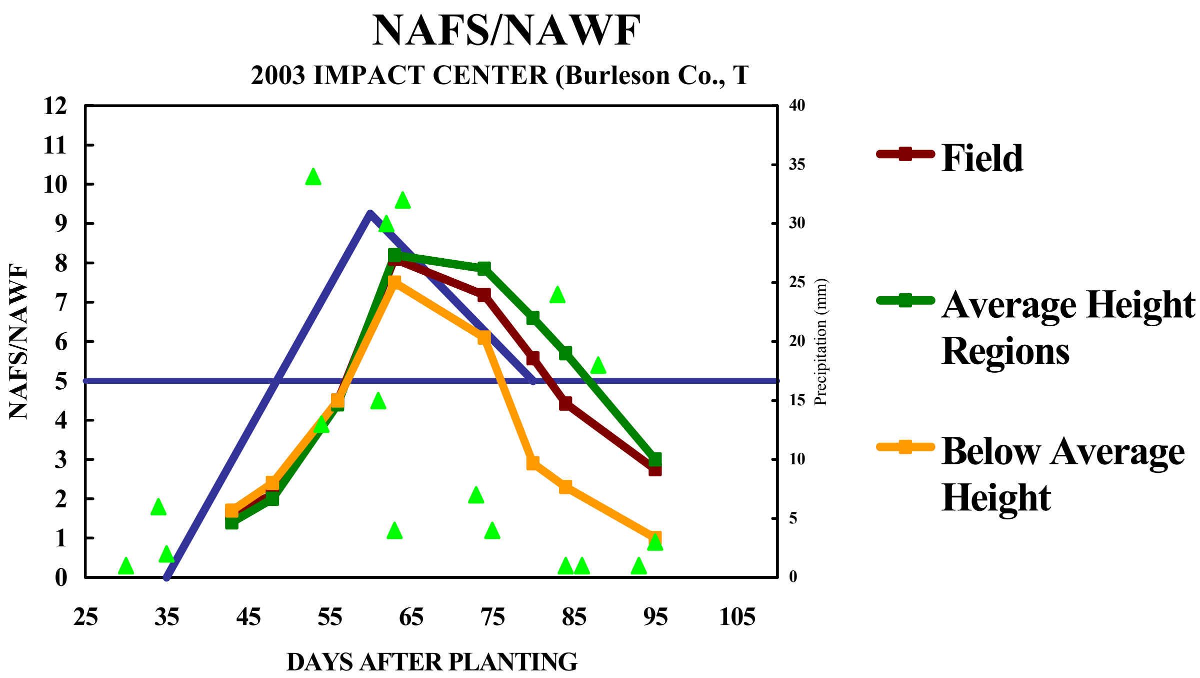


Figure 4: Average Height Locations and Regions.



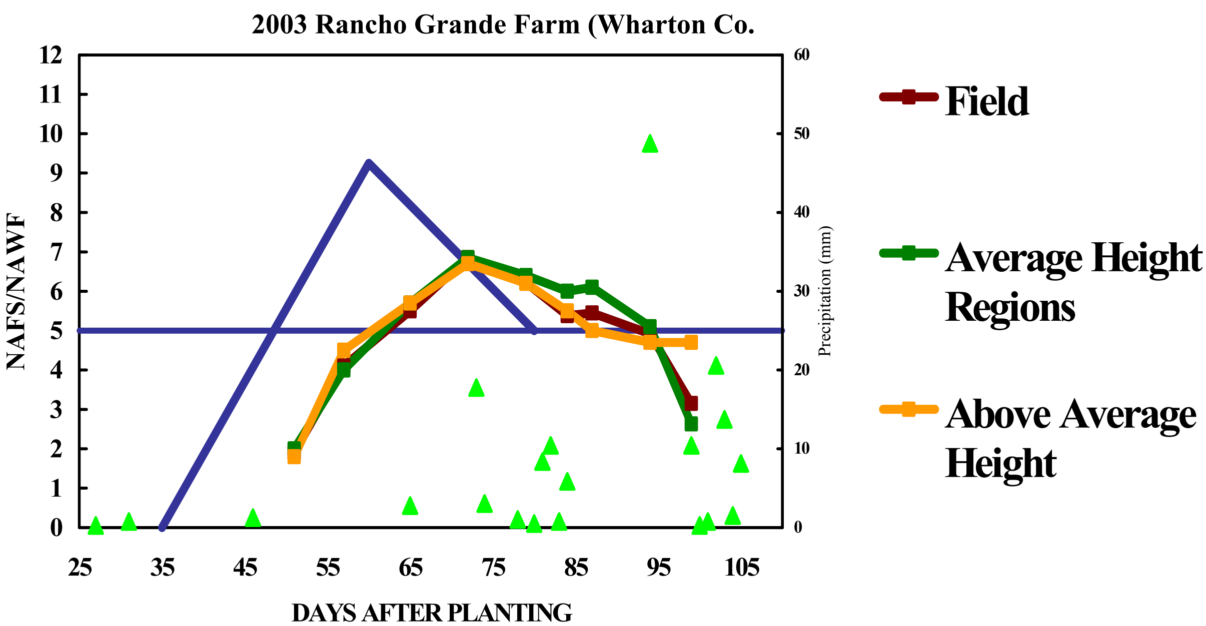


Figure 5: NAFS/NAWF Development Curves for Irrigated Sites (Triangles show dates and amounts for rainfall events.

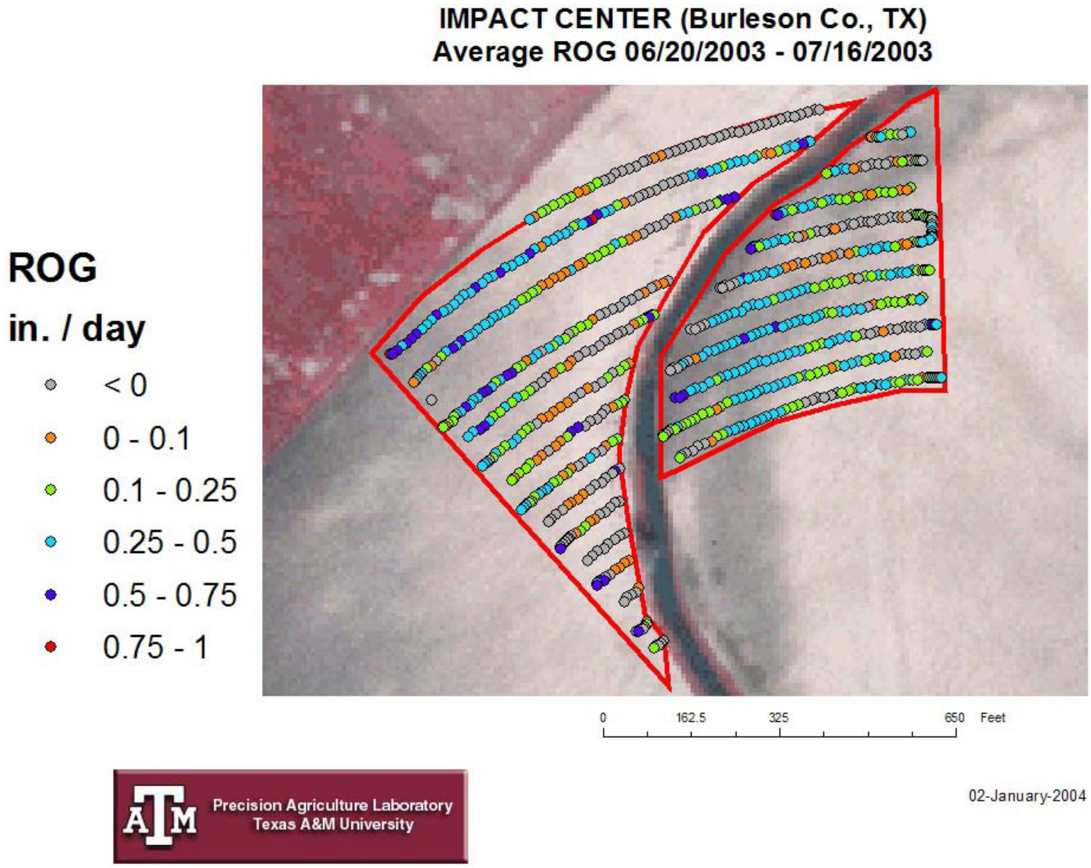


Figure 6: Rate of Growth Map.