



Prototype of 3D visualization tool for precision agriculture analysis  
by Paula Dolores Sanchez Alvarez

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in  
Computer Science

Montana State University

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Abstract:

The techniques to be developed in the precision agriculture three-year project, led by Dr. Dan Long, should improve farm profitability and minimize expenses and pollution of ground water by maximizing efficient use of fertilizer and other nutrient inputs to increase crop yields. A 3D visualization tool that incorporates terrain modeling and precision agriculture will enable farmers to manage their fields more efficiently for better crop yields. The software application will also lead to modification of existing education modules which can be adapted for training professionals, farmers, and students in geospatial and precision technologies.

A prototype of the application was developed in Java with the Java3D API because of the portability across operating systems and platforms and facilitation of the creation of 3D graphics used in scientific visualization, animation, web site design, simulations, virtual world construction, training, and design automation. This software will be available for the vast majority of farmers, students, and scientists. This prototype of the application is a proof of concept that demonstrates that a user friendly 3D Visualization Tool for Precision Agriculture can be developed in the Java language using Java 3D API. It is one of the few applications that create 3D models that would help to comprise large size data and display it in a meaningful way to apply precision agriculture techniques to any field for which the data is collected.

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FOR PRECISION AGRICULTURE ANALYSIS

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A thesis submitted in partial fulfillment  
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APPROVAL

of a thesis submitted by

Paula Dolores Sanchez Alvarez

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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Date

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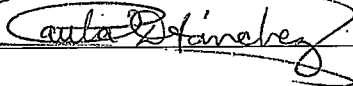
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A handwritten signature in cursive script, appearing to read "Paula D. Ramirez", written over a horizontal line.

Date

Apr 21 / 2003

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## GLOSSARY

Geo-referenced Tagged-Image File Format (GEOTIFF). It is a type of raster file format useful for geo-referenced images. The GEOTIFF uses the same tags definition than a Tagged-Image File Format (TIFF) file format (one of the world's most popular raster file formats) with an extension of tags used to describe all "Cartographic" information associated with TIFF imagery obtained with satellite imaging systems, scanned aerial photography, scanned maps, digital elevation models, or as a result of geographic analyses. The GeoTIFF tags conform to a hierarchical data structure of tags and keys, similar to the tags implemented in the TIFF specification version 6. GeoTIFF uses just 6 MetaTags (GeoKeys) to encode dozens of information elements that follow the TIFF discipline in their structure and layout. New keys may be defined as needs arise, within the current framework, and without requiring the allocation of new tags from Aldus/Adobe.

Global Positioning System (GPS). It is a satellite-based navigation and location system. There are twenty-four communications satellites orbiting the Earth that continuously transmit signals globally. GPS was originally for the U.S. military but now it is also available to the general public using proper equipment.

GPS Receiver. A device used to quickly and accurately determine the position (latitude, longitude or UTM coordinates and in most cases the altitude) of a point on or above the earth's surface. Survey grade GPS receivers find their position in tens of microseconds at accuracy up to centimeters.

Precision Agriculture. It is the use of the best technology available to adjust soil and crop management in order to apply the appropriate procedures depending on the status of every part of the agricultural field or tract.

Remote Sensing. The sensing of the Earth's surface from space by making use of the properties of electromagnetic waves emitted, reflected or diffracted by the sensed objects, for the purpose of improving natural resource management, land use and the protection of the environment (UN Annex to Resolutions 3234 and 3388). The ideal remote sensing system for precision agriculture is spectral resolution at the minimum of visible and near infra-red, spatial resolution of at least ten meters and with frequency of at least three days.

Universal Transverse Mercator (UTM) Coordinate System. It is a system of superimposed zones. A zone is a square grid system like the X,Y Cartesian coordinate system. There are 60 zones south of the Equator and 60 zones north of the Equator. The coordinates on a zone are called easting and northing coordinates. Their values are decimal based and in meters. The values for the zones in the north parts of the Equator go up from 0 to 10,000 m and for zones in the south part of the Equator go up from the South Pole from 0 to 10,000. The values for east-west

coordinates depend on the center of each zone called central meridian which has a width of three degrees of longitude to east and west. The central meridian of each zone is assigned the value 500,000 m. There are no East-West designators. Since the zones are superimposed on the easting coordinates, there are no values of 0 m for easting on any zone.

Terrain Modeling (Geo-morphometry). It is the quantitative representation of topography. It is the practice of ground-surface quantification.

## ABSTRACT

The techniques to be developed in the precision agriculture three-year project, led by Dr. Dan Long, should improve farm profitability and minimize expenses and pollution of ground water by maximizing efficient use of fertilizer and other nutrient inputs to increase crop yields. A 3D visualization tool that incorporates terrain modeling and precision agriculture will enable farmers to manage their fields more efficiently for better crop yields. The software application will also lead to modification of existing education modules which can be adapted for training professionals, farmers, and students in geospatial and precision technologies.

A prototype of the application was developed in Java with the Java3D API because of the portability across operating systems and platforms and facilitation of the creation of 3D graphics used in scientific visualization, animation, web site design, simulations, virtual world construction, training, and design automation. This software will be available for the vast majority of farmers, students, and scientists. This prototype of the application is a proof of concept that demonstrates that a user friendly 3D Visualization Tool for Precision Agriculture can be developed in the Java language using Java 3D API. It is one of the few applications that create 3D models that would help to comprise large size data and display it in a meaningful way to apply precision agriculture techniques to any field for which the data is collected.

## CHAPTER 1

## INTRODUCTION

Statement of the Problem

Agricultural crops, such as wheat, corn, cotton, and sugar beets, are affected by nitrogen status in the soil at various stages of growth. There is a positive correlation between nitrogen levels and levels of grain protein and crop yields. The nitrogen status is typically determined by an analysis of plant tissue using a SPAD meter, which measures the chlorophyll in the leaf [Westcott et al. 1997b]. The diagnostic information obtained from these measures enable agronomists to predict grain protein levels based on Nitrogen levels in the case of wheat [Westcott et al. 1997a] and in the case of corn [Wood et al. 1992] and cotton [Hickey et al. 1996; Saranga et al. 1998], crop yield. These predictions are necessary to determine whether the crops would benefit from additional applications of nitrogen at the various stages of crop growth.

Nitrogen in fields is not easily determined using current methods. Plant tissue testing to determine the need for late season Nitrogen application is contraindicated to improve sugar beet yields because of potential over application of Nitrogen which can increase vegetative growth at the expense of root sugar concentration [Moraghan and Smith, 1996]. In addition, it is not easy to identify Nitrogen deficient parts of fields, while also determining the spatial patterns in quality of the crops within the fields due to the high cost and lack of time that the field sampling would require. An accurate and

more rapid method of soil nitrogen status and quality crop determination which does not involve extensive ground sampling is needed.

Crop foliar Nitrogen has been predicted based on spectral properties of the crop canopy [Curan, 1998]. Analysis of differences in light reflectance from the crop canopy using the SPAD chlorophyll meter has also been effective [Westcott et al. 1997b]. These two techniques can be applied to remote sensing thereby making it possible to identify Nitrogen levels within a whole field at the same point in time.

The topography of the terrain also influences soil nitrogen levels and crop yields because it determines the distribution of such biophysical variables as water, solar radiation, and other nutrients in the soil. A GPS receiver can be used to gather easting, northing, and elevation grid points which transect a farm field. Interpolation software can be used to process the coordinates to develop a Digital Elevation Model (DEM) which can be used to determine terrain characteristics that describe the biophysical variables of the landscape [Moore et al. 1993]. The DEMs can reveal spatial variability in topography and correlated processes of the land surface that were unable to be gathered in the past [Gessler et al. 1995; 2000]. These techniques allow precision agriculture to do predictive modeling of landscape processes and variables which determine soil fertility and crop yield. Determining these relationships is important, especially in sub-humid and semiarid regions in the United States. While these techniques show great promise for precision agriculture, they are not extensively used at the current time.

One of the major barriers to use remote sensing in precision agriculture is that few professionals are trained in land resource analysis and inventory, remote sensing techniques, and terrain modeling. In fact, due to recent developments in new technologies, acquisition of geo-referenced data has surpassed the ability to comprehend these data. An opportunity to improve training and visualization techniques can be realized through recent advances in computer graphics. Many scientific disciplines have developed applications for three-dimensional (3D) graphics and there is a need for such development in precision agriculture. There would be more extensive access to farmers and other professionals across states to increase their capacity in geospatial information, if 3D visualization tools were available through the internet.

#### IFAFS Objectives

As a result of recent developments in precision agriculture techniques and based on the need for increased training and professional development in the use of these techniques, Dr. Dan Long, the Principal Investigator of a grant funded by NASA and USDA joint called Initiative for Future Agriculture and Food Systems (IFAFS) whom has been developing a project which meets the following objectives:

1. Determine whether vegetation and topographic indices computed from remote sensing data and terrain models can improve prediction of crop Nitrogen status, and whether these indices can be used to predict the crop yield or crop quality response to late season Nitrogen application.

2. Use an unmanned aerial vehicle (UAV) for low-attitude remote sensing of soil and crop conditions within farm fields.
3. Develop 3D visualization tools for use with the Internet that will facilitate multidisciplinary, multi-state research, teaching, and outreach activities and add value to individual information layers from terrain models, remote sensing, and yield maps.
4. Enhance existing teaching and outreach programs with use of the 3D visualization and analysis techniques.

#### Thesis Purpose

The techniques developed in this precision agriculture project should improve farm profitability and minimize pollution of ground water by maximizing efficient use of fertilizer and other nutrient inputs to increase crop yields. The purpose of this thesis is to develop a prototype of a 3D visualization software application that will incorporate terrain modeling and remote sensing which will enable farmers to have access to tools which will allow them to more efficiently manage their fields for crop yields. The software application will also lead to modification of existing education modules which can be adapted for training professionals, farmers, and students in geo-spatial and precision technologies.

## CHAPTER 2

## BACKGROUND

The purpose of this thesis project is to develop a prototype 3D visualization software application for precision agriculture and terrain modeling analysis. This software will enable farmers to have access to tools which will allow them to more efficiently manage nutrient applications to fields to enhance crop yields. The software application will also lead to modification of existing education modules which can be adapted for training professionals, farmers, and students in geospatial and precision technologies.

The following section describes the background which served as the basis for the current thesis project. The impetus of this project was based on the Initiative for Future Agriculture and Food Systems (IFAFS) proposal developed by Dr. Dan Long, researcher and professor at Montana State University - Northern Agricultural Research Center (MSU-NARC) in Havre, Montana.

#### Remote Sensing of Crop Nitrogen Status

Soil nitrogen is important for grain protein quality and crop yields in agriculture. The standard method agronomists use to assess nitrogen levels is to do an analysis of the plant tissue by using a SPAD meter which measures the chlorophyll in the leaves [Westcott et al. 1997b]. Agricultural crops, such as wheat, corn, cotton, and sugar beets require intense management to determine nitrogen status during the late season.

Information regarding nitrogen status is used to determine nitrogen adequacy and to predict grain protein quality in the case of wheat, and in the case of corn and cotton, crop yield [Wood et al. 1992; Hickey et al. 1996; Saranga et al. 1998]. For example, if nitrogen is applied as topdressing during the stage when the wheat is forming the heads, this application can significantly improve the concentration of grain protein [Westcott et al. 1997a]. Further, if nitrogen is applied as a side dressing in the late season for corn, it leads to increased yields (Ohio State University, 1995). In the case of cotton, even when the soil was not adequate to maintain yields, foliar applied nitrogen increased cotton yields. Sugar beets also benefit from proper nitrogen management. Too little nitrogen prevents growth, but too much nitrogen leads to increased vegetative growth but delays storage of sugar [Campbell and Kern, 1983; Carter, 1986]. Due to the difficulties of achieving the correct balance of nitrogen, late season application is not recommended for sugar beets. No method has been standardized as to how to predict the final sugar concentration of the beet root based on leaf nitrogen status.

It is difficult for farmers to accurately, quickly and inexpensively determine spatial patterns of crop quality in their fields and to determine nitrogen deficiency in parts of fields. Current methods require extensive field sampling. Therefore, a rapid, accurate, and inexpensive method of assessing nitrogen status in fields is needed without relying on current ground sampling techniques.

Crop foliar nitrogen content has been predicted based on spectral properties of the crop canopy [Curan, 1998]. Further, research indicates that differences in light reflectance from the crop canopy measured by the SPAD chlorophyll meter also indicates

nitrogen status [Westcott et al. 1997b]. These two techniques can be applied to remote sensing and thereby the nitrogen status of the field can be determined at one point in time. Preliminary research shows that remote sensing shows promise for determining nitrogen status in wheat for management of late season nitrogen application to fields [Long et al. 2000]. There is a correlation between grain protein quality and red and near infrared reflectance values using spectral analysis of digital aerial imagery. Nitrogen deficiency has been estimated in corn as seen by a lighter green color on aerial imagery [Blackmer et al. 1996; Blackmer and White, 1997].

### Terrain Modeling

Topography leads to the redistribution of biophysical variables such as water, solar radiation, and other nutrients in the soil. A GPS receiver can be used to gather easting, northing, and elevation grid points which transect a farm field. Interpolation software can be used to process the coordinates to develop a digital elevation model (DEM) that can be used to determine terrain characteristics that describe the biophysical variables of the landscape [Moore et al. 1993]. The DEMs can reveal spatial variability in topography and correlated processes of the land surface [Gessler et al. 1995; 2000]. These techniques allow precision agriculture to do predictive modeling of landscape processes and variables which determine soil fertility and crop yield. For example, DEMs and terrain modeling methods were used to analyze hill slopes which were segmented into various components (Moore et al, 1993). Landscape elements and measurements of slope, aspect, and other terrain characteristics were determined. It was found that

topography accounted for significant differences in quantity of water retained in the soil which is used by crops. The topography is linked to underlying processes in the soil which redistribute the water from rainfalls. This analysis is beneficial, especially in semiarid regions in the United States.

While terrain analysis shows promise for more efficient management of nutrient applications in precision agriculture, it is not extensively used. A major obstacle to the use of remote sensing in precision agriculture is that few professionals are trained in areas such as land resource analysis and inventory, remote sensing techniques, and terrain modeling. In fact, due to recent developments in new technologies, acquisition of georeferenced data has surpassed the ability to comprehend these data. An opportunity to improve training and visualization techniques can be realized through recent advances in computer graphics. Many scientific disciplines have developed applications for three-dimensional (3D) graphics and there is a need for such development in precision agriculture. LandMapR (MacMillan et al. 1999) and TopoMetrix [Fels et al. 1996] are new PC software packages which allow users to compute terrain attributes such as aspect, terrain shape index, landform index, slope curvature, topographic moisture index, etc, which in general are based on landform geometry and water flow within the landscapes. Since crop yields and quality are contingent on nitrogen which varies with topography, terrain modeling could contribute much to precision agriculture techniques. Terrain modeling when complemented by remote sensing can be used to identify management areas for precision nitrogen management.

The development of 3D visualization software which links remote sensing and terrain modeling would also lead to more extensive access to farmers and other professionals across states to increase their capacity in geospatial information, if the 3D visualization tools were available.

### Geospatial Sciences Professional Development

Few individuals have received training in remote sensing techniques and terrain modeling, especially in rural communities which do not know the potential benefits of this technology. Visualization techniques are important to use a person's visual skills to better comprehend relationships in spatial-temporal nature of biophysical phenomena. Since 3-Dimensional graphics displays stimulate more of the neurons in problem solving and simulate spatial reality, they can enhance analysis of data and lead to better understanding of changes in elevation [Van Driel, 1989]. Therefore, 3D visualization software has advantages over 2-dimensional contour maps which first require building a conceptual model of the relief prior to analysis (Swanson, 1996).

Examples of 3D visualization to do problem solving have been implemented through the Education Public Access Resource Center (Ed-PARC) which has successfully unified K-12 teachers, science teachers, and scientists into an Earth System Science team. The Ed-PARC disseminates information among its members and it tries to encourage students to go into careers in science, mathematics, engineering, and technology. In addition, local learning groups have been established in Montana, North and South Dakota, Minnesota, and Georgia [Long, 2000] These learning groups are

made up of farmers, scientists and their students, and extension members. The goal of these partnerships is to interrelate and share research about precision agriculture with practical farm implementation.

Other disciplines, such as geology, geophysics, hydrology, climatology, architecture, and engineering, have already included 3D computer graphics into its discipline and there is a need to do so in precision agriculture. With 3D visualization software aiding precision agriculture, the quantity and quality of the information and access to it, exchanged between researchers, educators, and professionals and farmers in agriculture would improve significantly.

Development of the 3D visualization software which will be incorporated into terrain modeling will assist farmers to increase profitability by maximizing their efficiency in the use of fertilizer and to minimize waste streams which can contaminate ground water.

#### Software Development and Use of JAVA 3D

To develop the 3D visualization software rapid prototyping was chosen as the design methodology [Tripp and Bichelmeyer, 1990) and involved three stages: assess user needs, design prototypes, and construct prototypes. During the user need assessment stage, the desired functionality of the software will be solicited from the end-users. Each learning group in Montana, the Dakotas, Minnesota, and Georgia determined the functionality of the program in terms of user friendliness, use for different types of data, and quality of visual display. This input was used to develop the software application in

stage two. Java 3D was used as the programming language. Finally, the third stage of prototyping will involve the use of Java Media Format Application Programmers Interface (JMF API) to develop the educational side of the application.

JMF API allows for Java based graphics to be integrated with sound and other media. This feature will be necessary in the development of educational materials related to the project which will be delivered not only through DVDs and CDs, but also through the Internet. The software will be able to run on Windows and Linux operating systems. The users will access Java applets by clicking on a Web page, another important feature of Java. In addition, the software will be available for download over the internet, so that users can run it on their own computers.

The purpose of this thesis project is to develop a prototype of 3D visualization software which incorporates functionality for education and research use in precision agriculture.

## CHAPTER 3

FUNCTIONALITY OF THE 3D VISUALIZATION TOOL FOR PRECISION  
AGRICULTURE ANALYSIS

The program allows the user to manipulate the 3D model with the mouse for rotation, translation and zoom. It also allows rotating with the arrow keys so the user can look at the model from any angle and closeness, including inside the model. It creates 3D models with data files containing four different types of data: Surface, Aerial Picture, Soil Core, and Yield.

Surface Model

This model uses mainly data from GPS. This model is used to accentuate the relative difference on elevations of the field which helps the understanding of the re-distribution of water, solar radiation and soil materials on the field. The data is collected by driving a survey grade GPS receiver along a farm field. These data are referred to as an elevation file, and are in the form of a grid of easting, northing, and elevation points which are collected every certain number of meters. Figure 1 shows an example of the surface model with the data displayed as it was given. Figure 2 shows the same surface model with the exaggerated elevation.

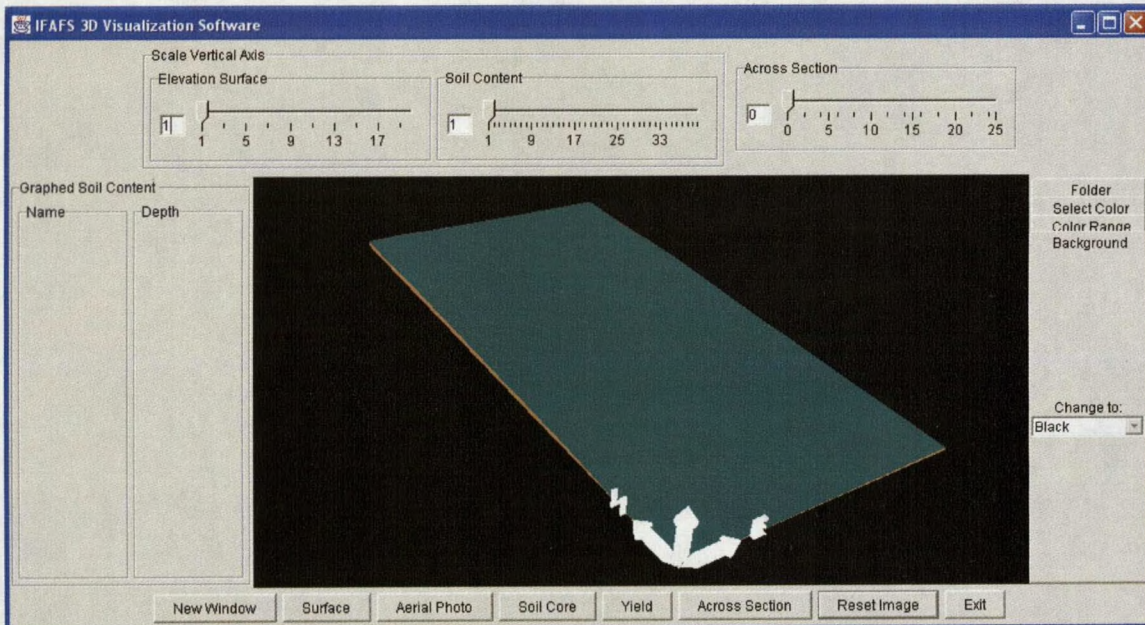


Figure 1 Surface Model

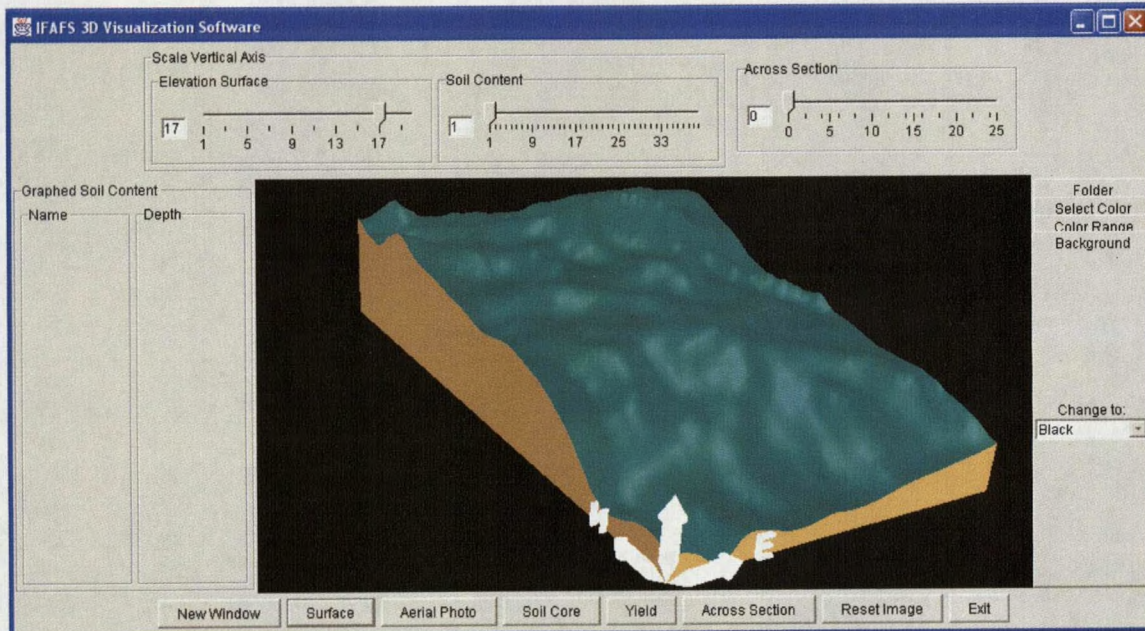


Figure 2 Surface Model with Same Data of Previous Figure with Elevation Exaggerated 17 Times.

### Aerial Picture Model

This 3D model offers a real view of the field by overlaying the image of the aerial picture onto the Digital Elevation Model (DEM) to enhance the human ability to visualize the spatial relationship between topographic relief, and image tones (i.e. brightness or darkness) or image color. The image used as an example is a color infrared image whereby the color green always appears in the false color of red. Typically, dark red relates to areas in fields of dark green, late-maturing crop whereas light red relates to areas of sparse, light green, early maturing crop. In this one example, one would be able to see that darker areas of crop are located in the lower, wetter areas of the field whereas the lighter areas are located in the higher, drier parts. It uses data from a GEOTIFF file interpolated with an elevation file. The elevation file is obtained as explained in the Surface type of model.

The GEOTIFF is a referenced image file. It was obtained from an original color slide film transparency digitized using a high-resolution Nikon Coolscan film scanner and applying referencing to the image with the tool GeoTIFF Examiner Software from Mentor Software, Inc ([www.mentorsoftwareinc.com](http://www.mentorsoftwareinc.com)). This tool creates the header information added to the TIFF and that is required for a GeoTIFF image file. In the current project, a tool was written to get into the format of the GEOTIFF file and extract the easting and northing Universal Transverse Mercator (UTM) coordinates and the Red Green Blue (RGB) color of the image. Then the UTM coordinates were interpolated with the elevation in order to position in 3D and construct the model of the surface with the real colors. The model is also manipulated as explained for the Surface model. Figure 3

shows the model of the surface with the real colors and the elevation exaggerated 15 times.

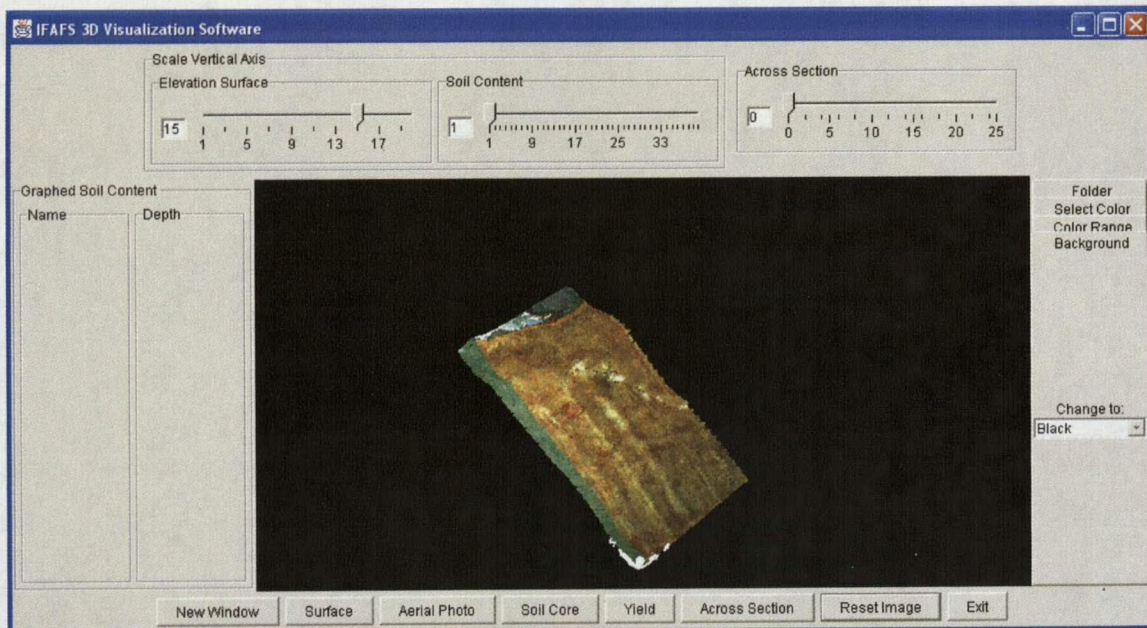


Figure 3 Aerial Picture Model with Exaggerated Elevation of 15 times.

### Soil Core Model

This 3D model offers an intuitive view of the content of the soil which helps characterize the distribution pattern of many soil attributes (e.g. nutrient levels, water, etc.). The soil samples are extracted from the soil core, analyzed in a laboratory and recorded on its content and position. For precision agriculture, it is necessary to analyze the different soil content on a field to manage well the crop. For some types of crops determining the right amounts of Nitrogen prior to crop planting, during early and late crop growth, helps maximizing quality and quantity and minimizing expenses and waste streams.

This data is also given only in the easting and northing coordinates. A scale of colors is assigned to every value obtained. The color indicated is dependent on the value. For example, the lower the content value the more blue the color and the higher the value the more red the color will be according to a RGB scale. The values at different depths compose a stack of cylinders with a layer for every value which is located relative to the place of excavation.

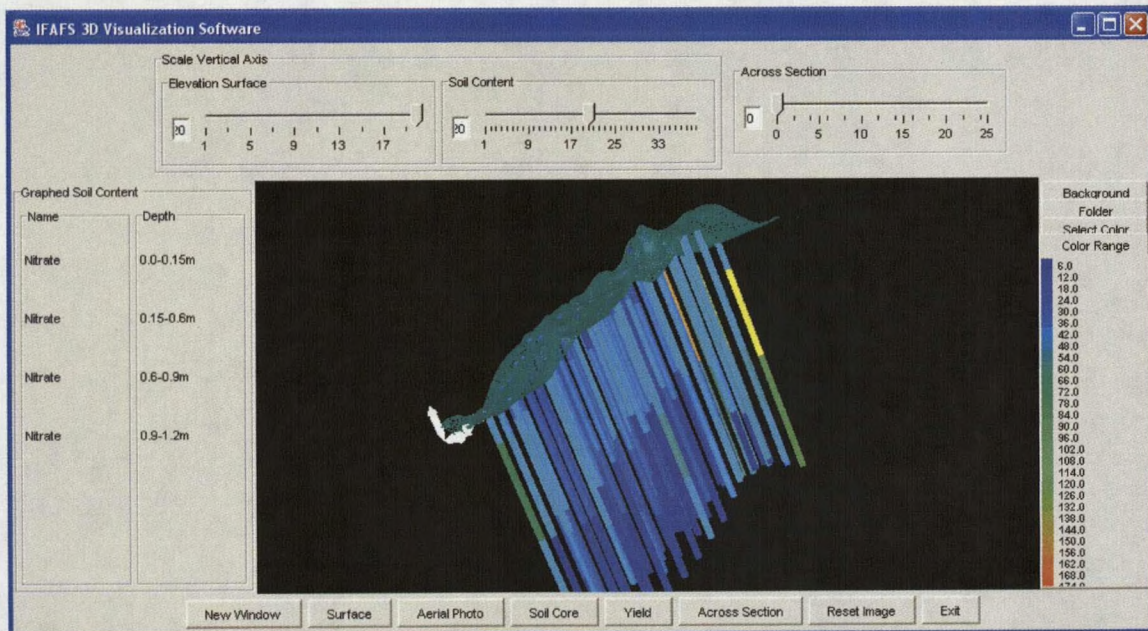


Figure 4 Soil Core Model with Surface and Elevation Exaggerated 20 times.

A 3D model is constructed by interpolating those UTM coordinates with the elevation file. This model gives the option of displaying the surface in wire mode, to offer the user the elevation of the field and the ability to exaggerate the elevation and soil core content separately. It also displays the model in slices so the user can observe certain parts of its content. Figure 4 shows the model of the surface and the soil core

content with exaggerated elevation of 14 times. Observe that the different levels at which the content values were taken are displayed on the left of the application window.

### Yield Model

This 3D model offers a means to visualize spatial patterns in crop yield in relation to the topography of the landscape for analyzing the reasons for that crop quantity. This data is collected using a combine harvester equipped with a mass flow sensor and a GPS receiver at one per second rate and saved in a computer as geo-referenced records of crop yield.

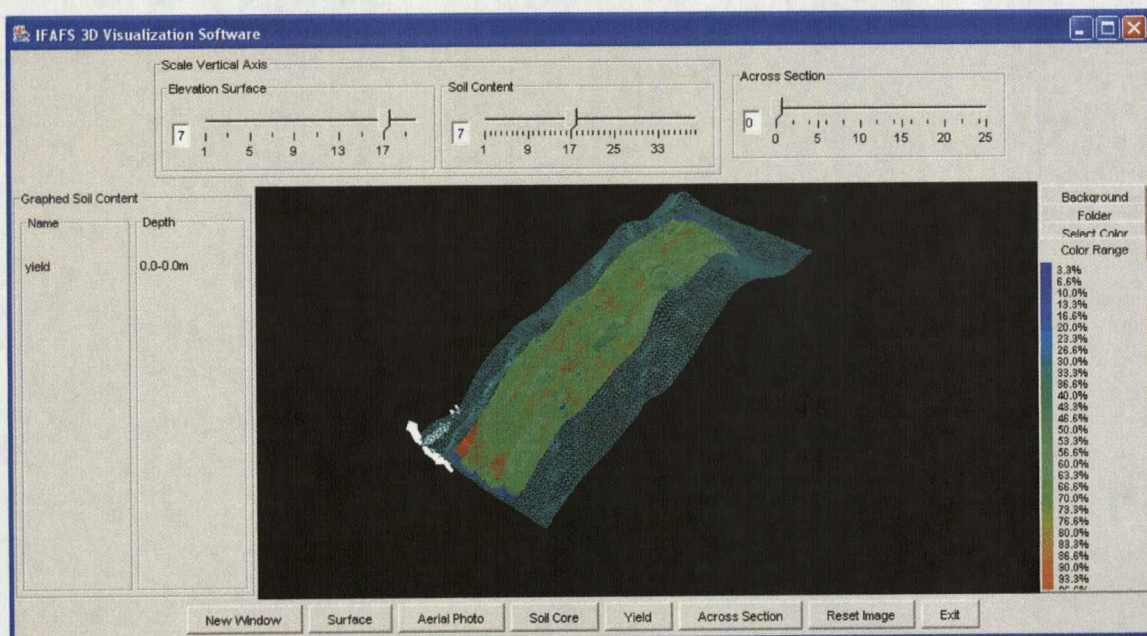


Figure 5 Crop Yield Model with Surface and exaggerated elevation of 17 times

The data provided is also in easting and northing UTM coordinates which is interpolated with the elevation file. The values corresponding to the evaluation of the yield are converted to color by a scale based on RGB values as explained previously for

Soil Core model. The 3D model is constructed and is available for the same type of manipulation as for previous models such as the option of displaying the surface on wire mode and exaggerating the elevation. Figure 5 shows the model of the surface and the yield content with exaggerated elevation of 17 times.

## CHAPTER 4

## REASON TO CHOOSE JAVA AND JAVA3D

Reasons to Choose Java

The Visualization Tool was desired to run on Windows and on Linux operating systems so the software is available for the vast majority of farmers, students, and scientists. Java has Write Once, Run Anywhere™ capability so it runs on virtually any operating system and across platforms. Java allows the development of portable applications. A portable application is compiled once and run in any operating system without having to port it using a compiler for that operating system and adjust to differences in computer hardware. This reduces time and cost of the implementation of the application. This is possible by compiling the source code of an application to obtain the byte-code of the application. The byte-code of the application is given as an input to any Java Virtual Machine which can handle all the details of the hardware where it is running.

Another very important characteristic of Java is the flexibility to create both applets and stand alone applications. The applets run on the Internet and locally. Also, the transformation from an applet to an application, and vice versa, is fairly easy and is usually possible in most cases.

The quality of Java being open source, allows the programmers to understand the language better and change it if necessary. Also, the Java Virtual Machine is free of

charge, which makes this project application easier to distribute and to be available for everyone.

Java was introduced in 1995, and since that time, it has become a very powerful computer programming language. Java is more robust and flexible as a language than previous languages, and therefore has allowed development of more kinds of programming applications such as those involving 3D graphics. Many software developers are now using Java. Up to 1998 there were nine hundred thousand developers and almost two hundred industry-leading technology companies who used Java [Siegel and Banks 1998]. By 2001, 2.5 million programmers used Java for development, and the numbers tend to keep growing [Kayl 2003].

#### Selection of the Java Compiler

At the beginning of the implementation the Java 2 Standard Edition (J2SE) 1.3 compiler was used but due to the large size of the files, the running time was more than the users wanted. The compiler that worked the fastest was Java Just In-Time Compiler (JITC) from IBM, which is compatible with J2SE 1.0.2 of Sun Microsystems. This version of Java runs ten times faster than J2SE 1.3. The primary reason this version of Java was selected for use in the development of the 3D visualization software was that it is completely compatible with the Sun Microsystems environment. The application was tested using the last J2SE version from Sun Microsystems, (J2SE 1.4.1) and it run well and but not as fast as IBM JITC.

The Java from Sun Microsystems is the standard, because in 2002, Sun was granted a preliminary injunction [Krim, 2002] requiring Microsoft Corporation to include the

Java platform offered by Sun Microsystems on every computer that is bought with its operating systems.

### Reasons to choose Java 3D (API)

The Java 3D Application Programming Interface (API) is a standard extension to the Java 2 platform. In the previous paragraphs we explained why the Java platform was selected. Another reason is the functionality of Java 3D, which allows for the creation of 3D graphics used in scientific visualization, animation, web site design, simulations, virtual world construction, training, and design automation.

Other reasons are the compatibility of Java 3D to interact well with video cards. Many video cards support OpenGL and DirectX which are then used to implement Java3D. Also, since Java is open source, changes to the library can be done if it is necessary. Java 3D applications have been presented since SIGGRAPH 1998 and many companies are incorporating Java 3D in their applications. (e.g. SolidWorks, SDRC, Brigham and Women's Hospital, WebScope, Improv Technologies, INT, LION Bioscience and Full Sail) [Siegel and Banks, 1998]. The version of Java 3D API used in this 3D Visualization project is 1.3 beta2 from Sun Microsystems.

## CHAPTER 5

## SUMMARY

Significance of the 3D Visualization Tool Application

This prototype of the application is a proof of the concept that demonstrates that the 3D Visualization Tool can be developed in the Java language using the Java 3D API. The GUI allows it to be a user friendly application. It has flexibility to show data from different land fields. It is one of the few applications that creates 3D models that would help to comprise large size data and display it in a more meaningful way to apply Precision Agriculture techniques.

Limitations

Due to the security levels of Java, this application when running as an applet on the Internet is not allowed to open files flexibly. That is why it was developed as an application which runs on the local machine. One alternative is to setup a database and access the data from the applet using Java Database Connectivity JDBC. This prototype does not determine the exact amounts of Nitrogen content through the Aerial Picture Model, because those parameters are still to be determined through the on-going research by the IFADS project.

### Recommendations for Improvement

This current project served as a prototype of a 3D visualization application for Precision Agriculture, the first of its kind. Given the strength of this application and its limitations, the following recommendations are offered for consideration to continue building on this project.

- Process and input the data for the different models into a database that can be accessed by the application via JDBC.
- Allow the user to pick on the model and obtain the 3D coordinates and other data being represented.
- Allow the designation of desired colors or patterns to different range of values for different types of models.
- Create models that show differences between datasets obtained at different times
- Create combinations of some of the models developed on the same canvas for a combined analysis.
- Give indicators of water flow and solar radiation through the topography analysis.

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APPENDICES

## APPENDIX A

### PROTOTYPE 3D VISUALIZATION FOR PRECISION AGRICULTURE

#### ANALYSIS TECHNICAL MANUAL

This appendix is a technical manual of the prototype of the 3D visualization tool for precision agriculture analysis. Its focus is for an audience with a computer science background. It is meant to be a help for generating the data needed for the 3D models and understanding in more detail the implementation of the prototype. Appendix A and B have similar information but vary in the level of presentation. It is intended that readers select the appropriate Appendix for their work.

This is an application to create 3D terrain models with information relevant for precision agriculture. It allows the user to manipulate the 3D model so the user can look at the model from any angle and closeness, including inside the model. There are several different types of data that the application uses to create the models. They are elevation of the surface, aerial picture of the field, soil core content, and yield.

#### Surface Model

This model is used to accentuate the relative difference on elevations of the field which helps the understanding of the redistribution of water, solar radiation and soil material concentration in the field. It will display a 3D model of the real UTM coordinates and their respective elevation in a box style and with reference to the axis

(the northing axis with an arrow named N, the easting axis named E and the elevation axis).

#### Format of the Elevation File

The elevation file contains the number of rows and columns of the mesh to construct in the first two lines, as shown in Table 2. The next three lines are the axis and the minimum and maximum values of the UTM coordinates northing for X, eastern for Y and Z for elevation. Each line contains information for each axis. The rest of the lines are the coordinates of every point in the mesh. The values X, Y, and Z are UTM coordinates in meters of every point by columns.

---

```

100
50
X 579564.572 580221.784
Y 5408931.323 5410251.824
Z 924.5359 945.9545
579564.572 5408931.323 927.1337569
579577.9845 5408931.323 926.9972054
579591.397 5408931.323 926.885333

```

---

Table 1 Example of First Lines of an Elevation File

### Implementation Considerations for the Surface Model

#### Coordinates

The easting values are visualized on axis "X", northing values are visualized on axis "Z" and elevation values are visualized on axis "Y." The values on axis "Z" are inverted, so the increase of the northing coordinate goes into the screen.

### Data Normalization

In order to have a more standard area of viewing, the coordinate values are normalized, so all of the values displayed are approximations of real decimal values between zero and one, so that they will display well with the Nominal Viewing Transform.

### Mesh

In order to create 3D objects in Java3D it is necessary to give the coordinates as a set of triangles counter-clockwise interleaved with clockwise for the front part as a sequences of triangles (strips) which are made row by row.

### Manipulation

The manipulations were done at first with behaviors controlling the mouse and arrow keys. They were changed for behaviors transforming the View Platform instead, because the application simply needed to transform the entire scene. This changed the problem from transforming every object in the scene into only transforming the View Platform. Exaggeration of the elevation is done by scaling the "Y" axis, according to the slider bar or text field requests. Also, the model can be re-positioned to the initial view by resetting the View Platform.

### Data Source

Most farmers and scientists have access to GPS receivers. There are many models on the market that have different accuracy, speed, and storage capacities. Survey grade

GPS receivers can be mounted on a vehicle, and record the 3D positions at a speed of tenth of a second and accuracy up to fractions of a centimeter.

### Data Collection

This model uses mainly data from GPS receivers. The data is collected by driving a survey grade GPS receiver along a farm field. The receiver collects the elevation point as a UTM coordinate with easting, northing, and elevation coordinates every certain number of meters. Certain software (e.g. Surfer by Golden Software, GS+ package from Gamma Design Software) generate a systematic grid by interpolating the coordinates values that form a rectangular grid from the points. The data is referred to as an elevation file.

### Proposed Improvements

The data from the GPS-receivers should be input into a database, generating the appropriate statistical information that the 3D Visualization Tool needs in the format required for an elevation file and with the details on normalization of values. Another alternative is not to require that the points are in a rows and columns order, but ordering the data by the first coordinate, and then with the second coordinate, so the coordinates are listed by rows and columns.

### Snapshots

The model of the elevation is shown as a boxed surface. Figure 6 shows an example of the surface model with the data displayed as it was given, with some rotation. Figure 7 shows the same surface model with the exaggerated elevation.

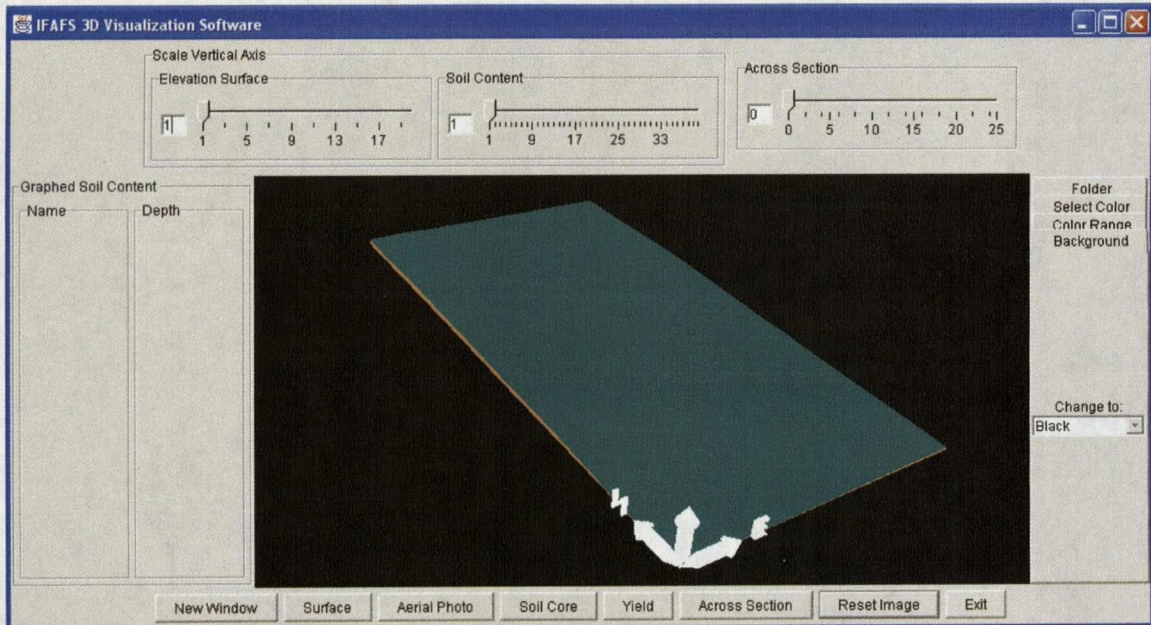


Figure 6 Snapshot of the Surface Model

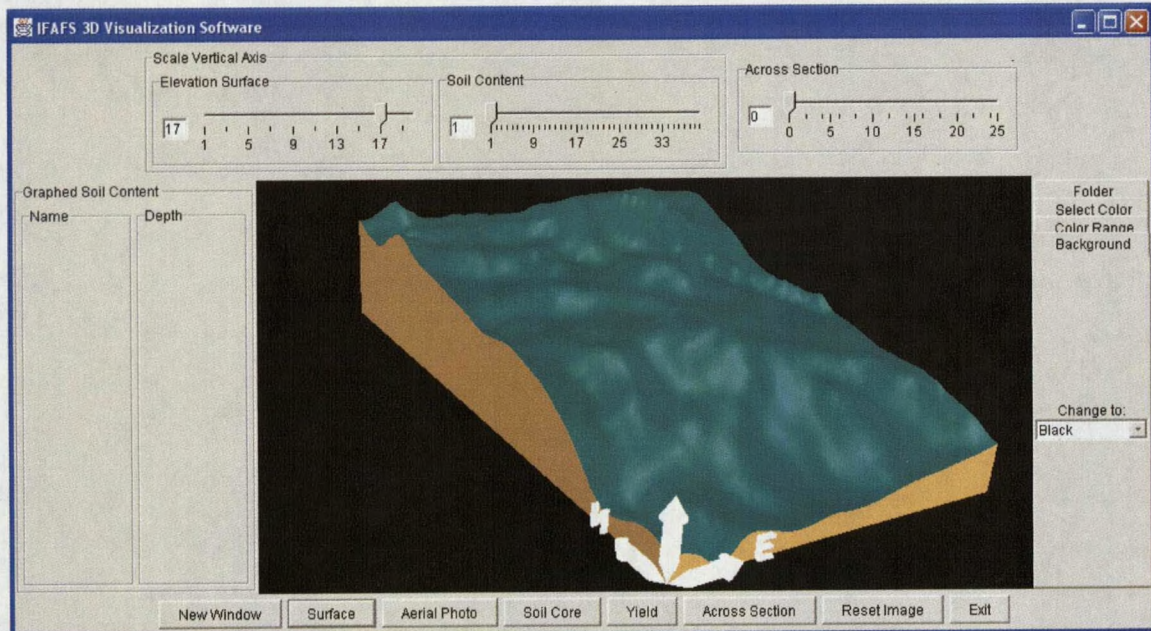


Figure 7 Snapshot of the Surface Model with Elevation Exaggerated 17 Times.

### Aerial Picture Model

This model offers a real view of the field by overlaying the image of the aerial picture onto the Digital Elevation Model (DEM) to enhance the human ability to visualize the spatial relationship between topographic relief, and image tones (i.e. brightness or darkness) or image color. The image used as an example is a color infrared image whereby the color green always appears in the false color of red. Typically, dark red relates to areas in fields of dark green, late-maturing crop, whereas light red relates to areas of sparse, light green, early maturing crop. It will display a 3D model of the real UTM coordinates and their respective elevation with the real color and the reference to the axes.

#### Format of the Aerial Picture Data File

The Aerial Picture Data File contains the number of 3D points in the file, as shown in Table 2. The next three lines are the axis and the minimum and maximum values of the UTM coordinates northing for X, eastern for Y and Z for elevation. Each line contains information for each axis. The next line is the minimum and maximum possible values of RGB (red, green, blue). The rest of the lines are the coordinates of every point and the RGB values and transparency of it. The easting, northing and elevation values of a 3D point are in meters and the points in any order in the file.

---

2939  
X 579566 580221  
Y 5408940 5410230  
Z 924.79 945.79  
C 0 255  
579566 5410230 937.58 106 158 110 255  
579852 5410230 937.21 197 255 215 255  
580138 5410230 937.79 66 78 61 255

---

Table 2 First Lines of an Aerial Picture File

### Additional Implementation Considerations from the Surface Model

#### Data Normalization

If the elevation data file was also provided, the UTM coordinates and elevation values from the GeoTIFF data file are normalized according to the elevation data file.

#### Color Extraction

In the current project, a tool was written to extract the UTM coordinates, the RGB colors and the transparency from the GEOTIFF file. The UTM coordinates obtained from the GeoTIFF image were interpolated with the elevation file in order to obtain 3D points and construct the model of the surface with the real colors in the right position.

#### Data Source

Scientists will be able to obtain the referenced image files in GEOTIFF format collected from a slide film transparency taken from an airplane and digitized using a high-resolution Nikon Coolscan film scanner, pilot-less plane (drone) with a digital camera or satellite.

A drone was obtained through the IFAFS grant. It is reliable, not too expensive, transportable and easy to operate. Users can control it automatically from the ground. The drone can have a digital camera, a GPS receiver, a gyroscope or a radio transmitter. Also, NASA offered to provide satellite images, which will come in GEOTIFF format. Most people would be able to obtain these images from the satellites.

### Data Collection

For this example, the original Tiff file was created from a film transparency that had been digitized with a Nikon Coolscan Film Scanner. The GeoTIFF Examiner Software from Mentor Software, Inc. ([www.mentorsoftwareinc.com](http://www.mentorsoftwareinc.com)) was used to create the header information that could be added to the Tiff to create a GeoTIFF. The data is collected by taking the GEOTIFF format file and extracting from it the RGB values, the transparency value and the position in UTM coordinates. Then this data is interpolated with the elevation data to obtain the 3D points.

### Proposed Improvements

The data should be extracted from the GEOTIFF image and it should be input into a database in the Aerial Picture Data file format. The 3D Visualization Tool should get the GeoTIFF data from the database to display it.

### Snapshots

The model is a set of points with exaggerated radius and displaying the real color, located in the UTM position and corresponding elevation. Figure 8 shows the rotated model of the surface with the real colors and the elevation exaggerated 15 times.

Observe that darker areas of the crop canopy are located in the lower, wetter areas of the field whereas the lighter areas are located in the higher, drier parts of the field.

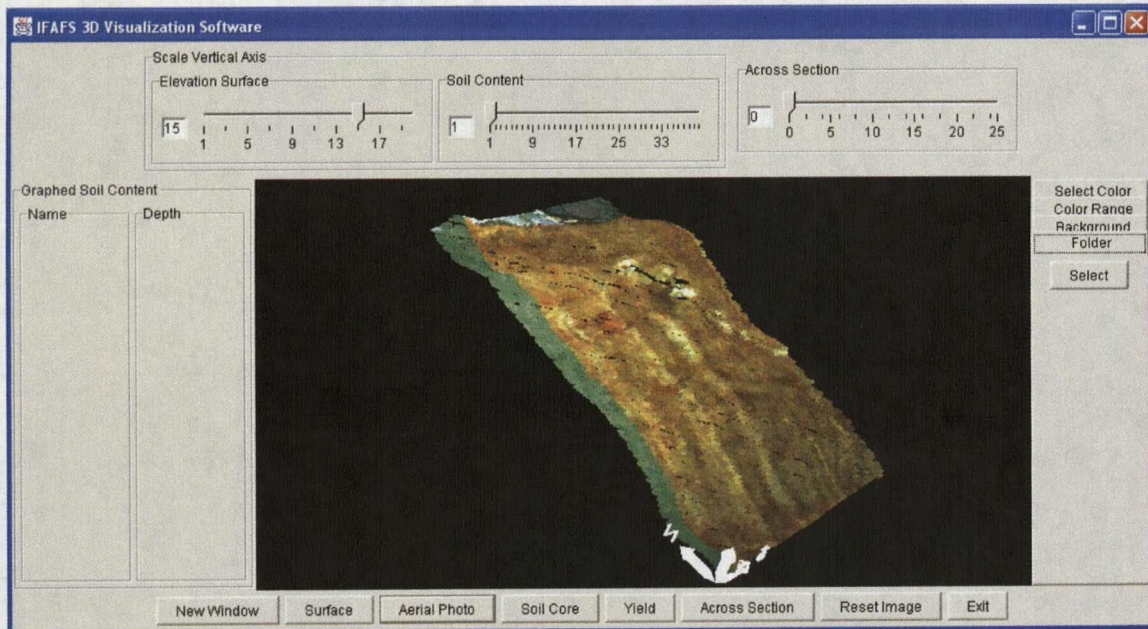


Figure 8 Snapshot of the Aerial Picture Model with Exaggerated Elevation of 15 Times.

### Soil Core Model

This 3D model offers an intuitive view of the content of the soil which helps characterizing the distribution pattern of many soil attributes (e.g. nutrient levels, water, etc.). The soil samples are extracted from the soil core, analyzed in a laboratory and recorded on its content and position. For precision agriculture, it is necessary to analyze the different soil content on a field to manage well the crop. For some types of crops determining the right amounts of Nitrogen prior to crop planting, during early and late crop growth helps maximizing quality and quantity and minimizing expenses and waste streams.

This data is also given only in the easting and northing coordinates. A scale of colors is assigned to every value obtained. The color indicated is dependent on the value. For example, the lower the content value the more blue the color and the higher the value the more red the color will be according to a RGB scale. The values at different depths compose a stack of cylinders with a layer for every value which is located relative to the place of excavation.

A 3D model is constructed by interpolating those UTM coordinates with the elevation file. This model gives the option of displaying the surface in wire mode, to offer the user the elevation of the field and the ability to exaggerate the elevation and soil core content separately. It also displays the model in slices so the user can observe certain parts of its content. Figure 4 shows the model of the surface and the soil core content with exaggerated elevation of 14 times. Observe that the different levels at which the content values were taken are displayed on the left of the application window.

#### Format of the Soil Core File

The soil core file contains the number of soil content values to graph, as shown Table 4. The next three lines are the axes and the minimum and maximum values of the UTM coordinates northing for X, eastern for Y and Z for elevation. Each line contains information for each axis. The next two lines are the minimum and maximum possible values of the soil content measured and the level (the starting and ending depth) of the averaged value. The rest of the lines are the coordinates of every point and the corresponding content value. The point values are in any order.

---

```
60
x 579722.68 580033.58
y 5409025.81 5410214.53
z 927.052248 945.096408
c 0 180
level1 0 0.15
579722.68 5409025.81 927.052248 36
579795.84 5409025.81 927.591744 26
579887.28 5409025.81 927.954456 26
579978.72 5409025.81 929.44188 12
```

---

Table 3 Example of First Lines of a Soil Core Content File

### Additional Implementation Considerations of the Surface Model

#### Data Normalization

If the elevation file is provided the normalization of values depends on those values also, so they are normalized using the same ratio.

#### Mesh

A mesh is constructed for the Elevation file. The difference is that for this model it is displayed in wire mode setting the polygon mode to line.

#### Cylinders

The cylinders position and height are initially exaggerated by 40 to be able to observe them better. Then the user can farther exaggerate them.

#### Soil Content

A color is assigned to every value according to a RGB scale. More blue will be displayed the lower the value and more red will be displayed the higher the value.

if ( value < 0.5 )

```
        color = new Color3f(0, 2*value, 1 - 2*value);
else
{
    float newval = 1-value;
    color = new Color3f(1 - 2*newval, 2*newval, 0);
}
```

### Manipulation

- The exaggerations of the soil core cylinders are done by scaling the “Y” coordinates of the cylinders by the requests of the slider titled “Scale Vertical Axis” and “Soil Core.”
- The “Across Section” allows to observe the model in many slices. This is done by changing the View Platform and setting the front and back clip planes at a distance proportionally to the number of slices the user specifies to divide the model. The slices are shown with a timer or with a user controlled pause. It will ask the number of slices to divide the model, and if the user wants to control the rate of display of the individual sections.

### Data Source

Researchers obtain the soil content data using a hydraulic soil sampling machine that is carried on a pickup truck to pick up the samples for a grid gathering 2-inch wide, 4 feet long steel tubes that are hydraulically pushed in the ground across a field and send this samples broken by foot to a laboratory, where the soil core is examined and the values of the soil core, such us N, PH, P, K, S, Mg, Grav. H<sub>2</sub>O, etc. are obtained.

### Data Collection

The data comes from the laboratory given the values of the UTM coordinate of the position of each of the sample tubes analyzed from the grid of the field and the values obtained from evaluating the nutrients. The data is best processed as it was obtained, but sometimes they are mixed together to obtain an average in the interest of minimizing costs. In that case, the mixed samples are from a unique part of the field (hilltop, basin, etc.) to form one sample, which essentially constitutes an average for that part of the field. Those UTM coordinates are interpolated with the elevation file to obtain the 3D position of the soil surface and to apply the depth difference.

### Proposed Improvements

The data should be input into in a database and obtained by the 3D Visualization Tool in the format required for the soil core file, with 3D points as normalized values, and scale used to normalize them. Also, the number of colors or pattern can be an input from the user, by ordering the data from the soil core content by the content value and creating a fixed number of ranges and assigning a different color to every range of values.

### Snapshots

The model of the elevation and soil core content is shown in Figure 9 which shows an example of the model of the surface and the soil core content with exaggerated elevation of 14 times. Observe that the different levels at which the average was taken is displayed on the left of the application window.

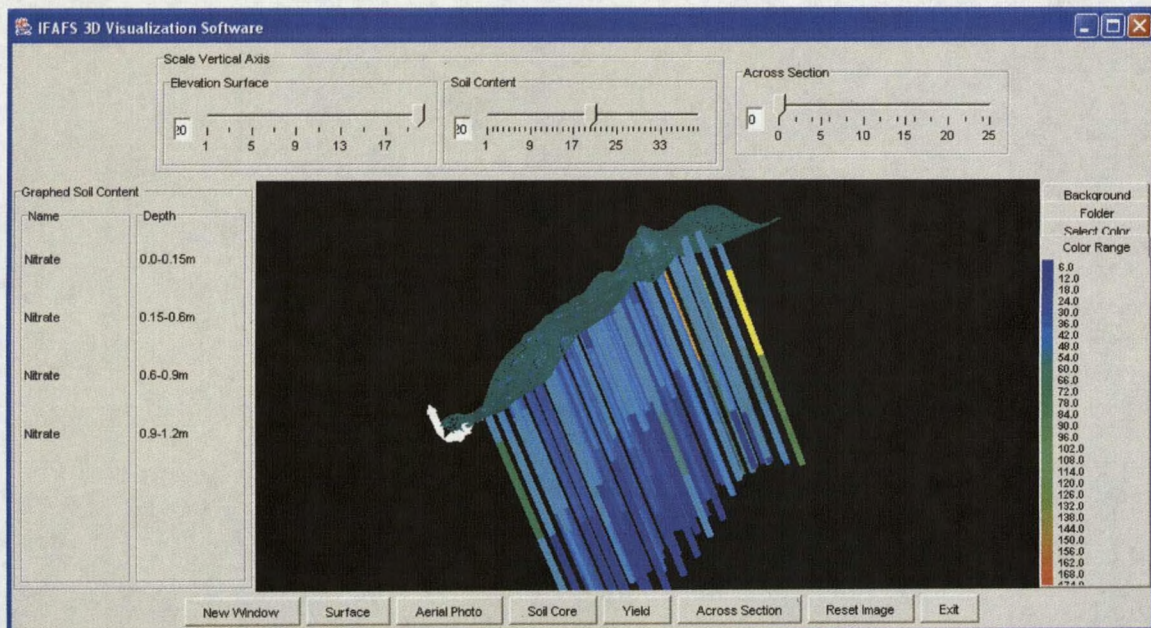


Figure 9 Soil Core Model with Elevation Exaggerated 20 times.

### Yield Model

This 3D model offers a means to visualize spatial patterns in crop yield in relation to the topography of the landscape for analyzing the reasons for that crop quantity. As explained in the Soil Core model section, this model also shows a wired surface when the elevation file is provided. It also shows circles of the quantity of the crop with the respective colors according to the evaluated value of the crop yield. The reference to the axes is shown as well.

### Format of the Yield File

The yield file contains the number of yield data to graph, as shown in Table 4. The next three lines are the axes and the minimum and maximum values of the UTM coordinates northing for X, eastern for Y and Z for elevation. Each line contains

information for each axis. The next two lines are the content minimum and maximum possible values of the soil content measured and the level and the starting and ending depth cylinder representing the yield. The rest of the lines are the coordinates of every point and the corresponding yield value. These values are in any order.

---

```

8821
X 579564.572 580221.784
Y 5408931.323 5410251.824
Z 924.5359 945.9545
c 0.1 59.2
579722.250000 5408955.500000 926.776428 2.800000
579722.250000 5408961.000000 926.798096 13.800000
579722.250000 5408965.500000 926.735168 22.500000

```

---

Table 4 Example of First Lines of a Yield File

### Additional Implementation Considerations to the Soil Core Model

#### Data Source

Researchers use a combine harvester equipped with a mass flow sensor and GPS receiver. The GPS geo-reference the yield data collected at a one second rate. A computer on board logs all the yield data.

#### Data Collection

This data is collected from the log that the computer recorded while on the combine harvester. The data provided include the yield values, their positions in easting and northing UTM and the value obtained by the mass flow sensor. The UTM coordinates are interpolated with the elevation data to obtain the 3D position.

### Proposed Improvements

As in the Aerial Picture Model, the data should be input into a database and generated in the format required for yield file with other related information like normalized 3D points and the scale used. Also, if the values were sorted by rows and columns, then it would be possible to create the mesh with the colors obtained by this and have more uniform shading.

### Snapshots

Figure 10 shows the model of the surface in wire mode and the crop yield quality represented by colors in the RGB scale with exaggerated elevation of 17 times.

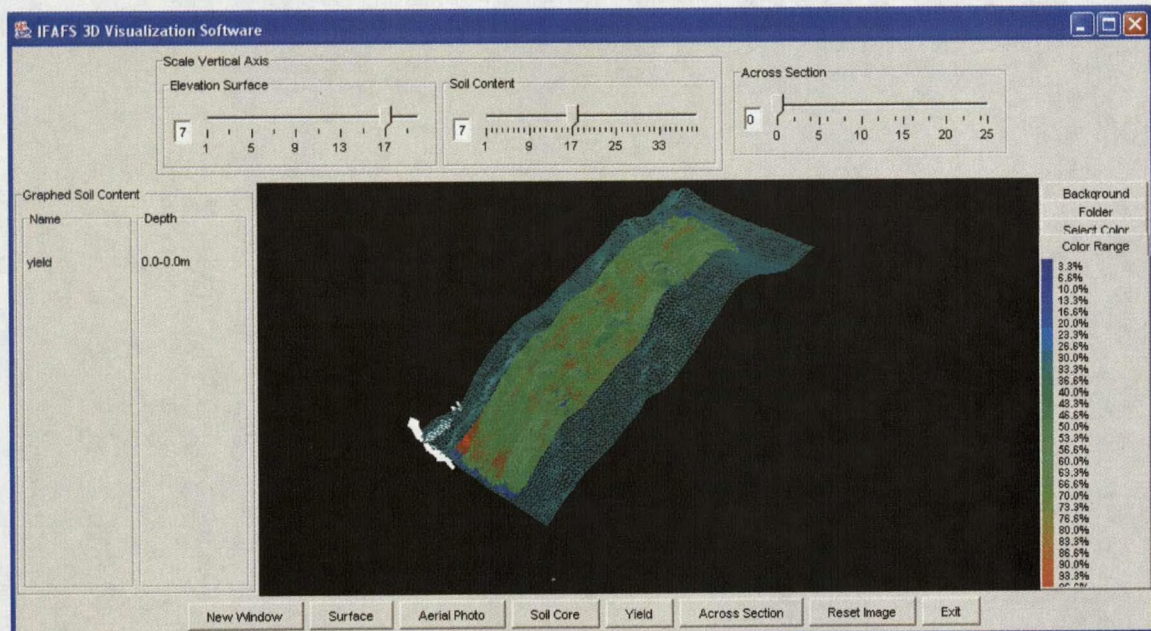


Figure 10 Crop Yield Model with exaggerated elevation of 17 times

Obtaining several windows to work with

Click on the button "New Window" to instantiate another object of this application.

The user can create as many models with different data types as the memory would handle.

APPENDIX B

## PROTOTYPE 3D VISUALIZATION TOOL FOR PRECISION

## AGRICULTURE ANALYSIS USER MANUAL

This appendix is a user manual of the prototype of the 3D visualization tool for precision agriculture analysis. Its focus is for all audiences. It is meant to be a help for users that will be manipulating the prototype at a higher level to create the 3D models. Appendix A and B have similar information but vary in the level of presentation. It is intended that readers select the appropriate Appendix for their work.

How to use the 3D Modeler Application

This application allows the user to manipulate the 3D model with the mouse for rotation, translation and zoom so that the user can look at the model from any angle and closeness, including inside the model. It creates 3D models. It also allows the user to use the arrow keys for the rotation in case the user does not want to use the mouse. There are several different types of data that the application uses to create the models. They are elevation of the surface, aerial picture of the field, soil core content, and yield information.

Obtaining several windows to work with

Click on the button "New Window" to obtain another window to create a model. The user can create as many as he/she wants.

### Reset Image

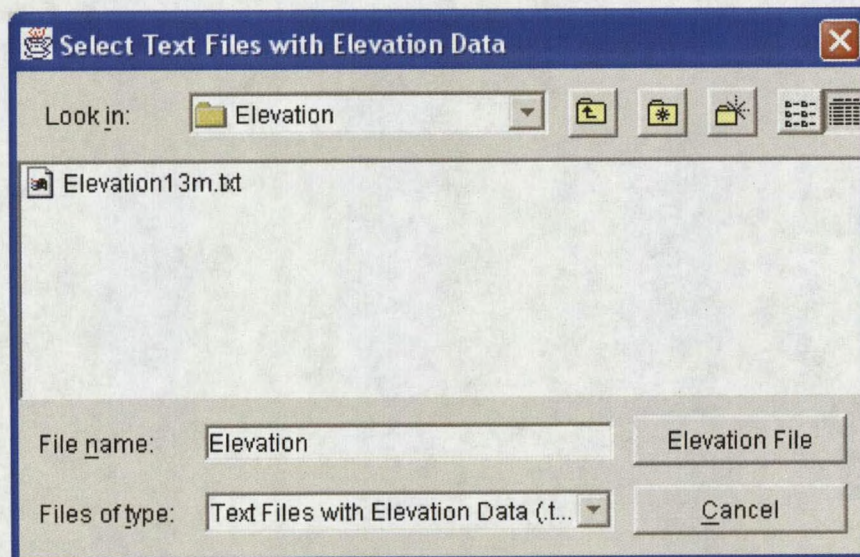
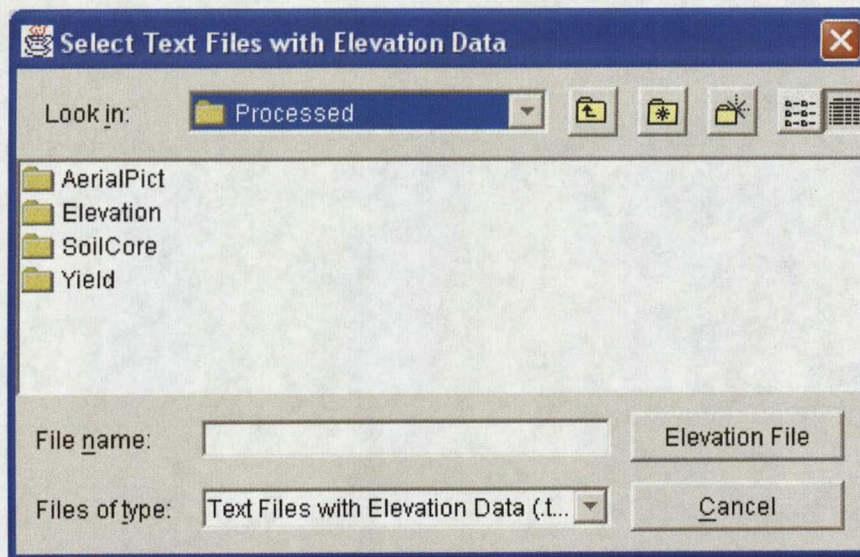
Click on the button “Reset Image” to re-position the model on the initial way, with the northing axis pointing away from the user, and the easting axis pointing to the right.

### Surface Model

This model is used to accentuate the relative difference on elevations of the field which helps the understanding of the re-distribution of water, solar radiation and soil materials on the field. It will display a 3D model of the real UTM coordinates and their respective elevation in a box style and the reference to the axis (the northern axis with an arrow named N, the easting axis named E and the elevation axis arrow without a name).

### Creating the Surface Model

- Execute the button “Surface.”
- Select the Elevation file.
  - a. A window titled “Select Text Files with Elevation Data” will show.
  - b. Browse through the folders on that window by double clicking on them.
  - c. Select the elevation file. The elevation example file is in folder Elevation, and its name is Elevation13m.txt.
  - d. Execute the button “Elevation file.”



### Format of the Elevation File

It contains the number of rows and columns of the mesh to construct in the first two lines. The next three lines are the axis and the minimum and maximum values of the UTM coordinates northern for X, eastern for Y and Z for elevation. The rest of the lines

are the coordinates of every point in the mesh. The values X, Y, and Z are UTM coordinates in meters of every point by columns.

---

```

100
50
X 579564.572 580221.784
Y 5408931.323 5410251.824
Z 924.5359 945.9545
579564.572 5408931.323 927.1337569
579577.9845 5408931.323 926.9972054
579591.397 5408931.323 926.885333

```

---

Table 5 Example of First Lines of an Elevation File

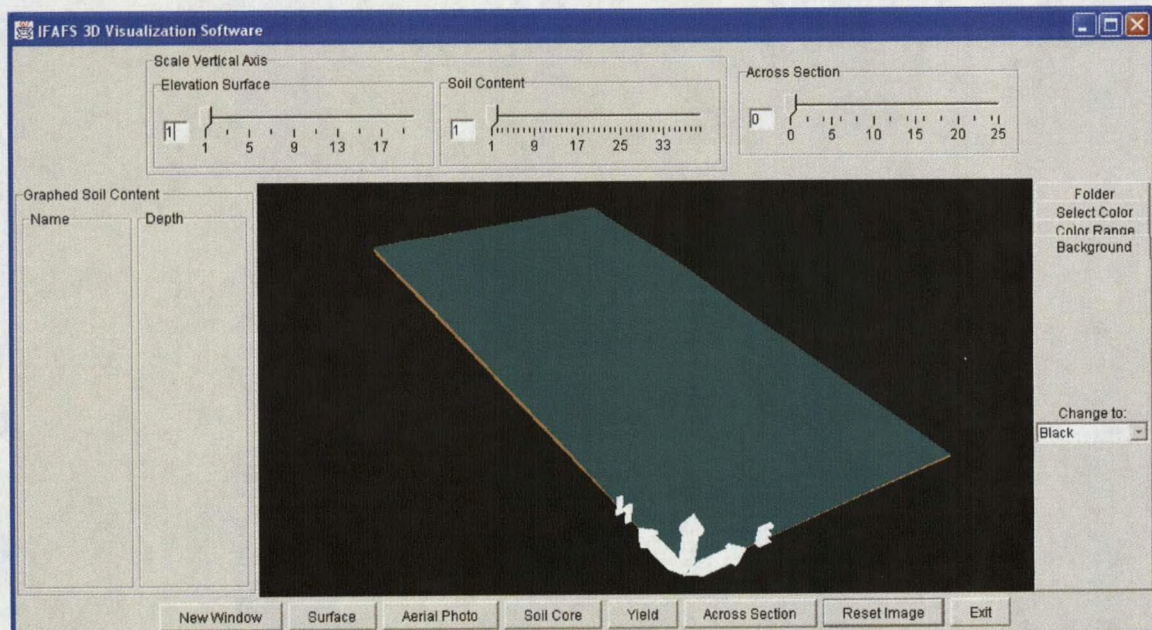


Figure 11 Surface Model

### Manipulating the Model

- Rotations are done drawing the model with the left button (the primary button) of the mouse in any direction. This also can be done with the keyboard with the left, right, up and down arrow keys.

- Translations are done drawing the model with the right button (the secondary button) of the mouse to any position.
- Zooming In/Out is done drawing the model with the middle button or the wheel of the mouse downwards/upwards respectively.
- Exaggerations of the elevation of the surface are done by drawing the point on the slider titled “Scale Vertical Axis” and “Elevation Surface” with the left button (the primary button) of the mouse. This also can be done with the keyboard by clicking Tab until that slider is selected and moving the arrow keys.

### Snapshots

The model of the elevation is shown as a boxed surface. Figure 11 shows an example of the surface model with the data displayed as it was given, with some rotation. Figure 12 shows the same surface model with the exaggerated elevation.

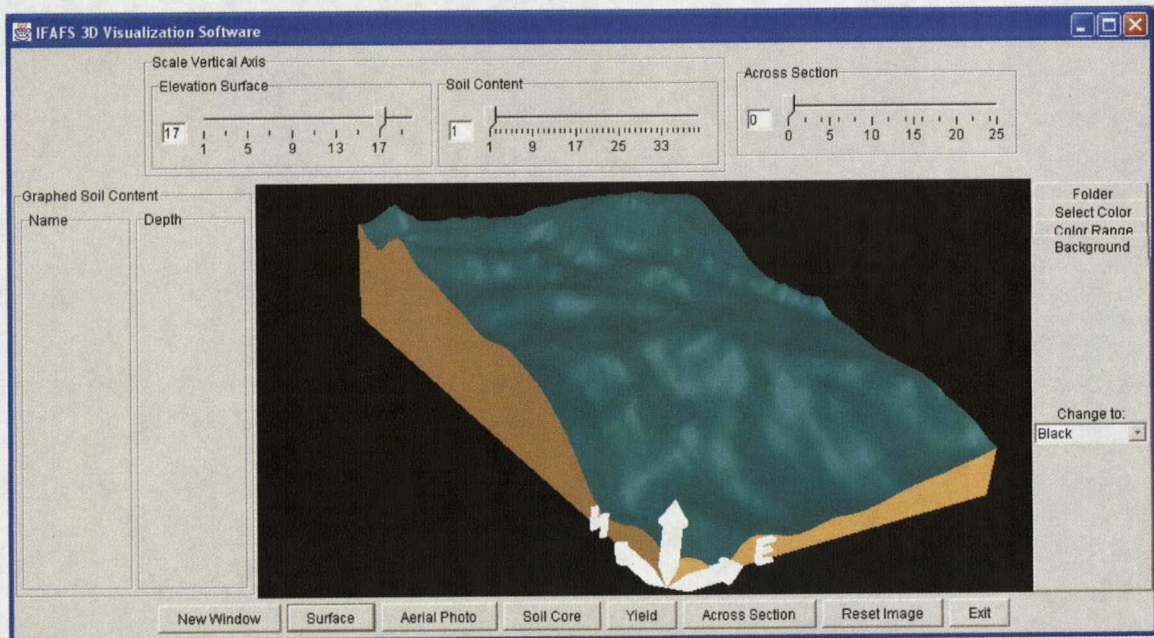


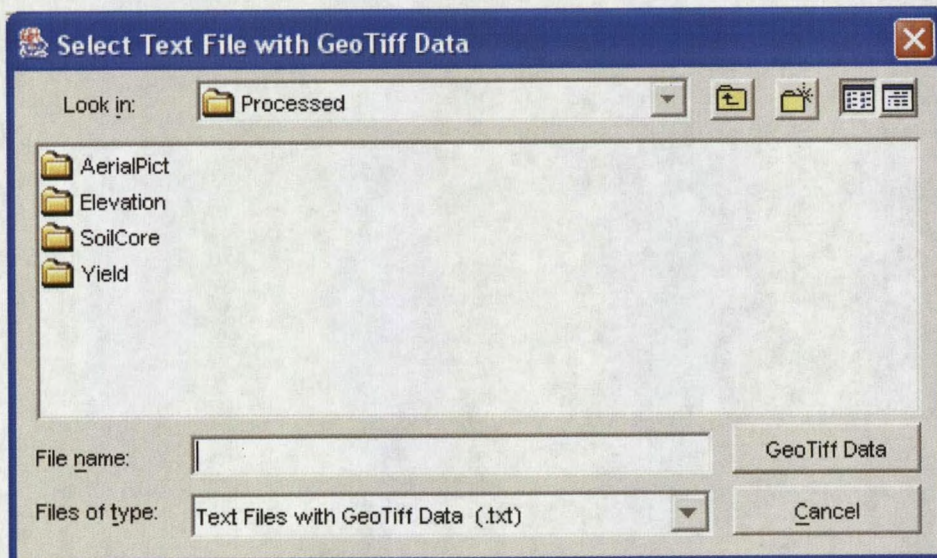
Figure 12 Surface Model with Same Data of Previous Figure with Exaggerated Elevation of 17 Times.

### Aerial Picture Model

This model offers a real view of the field to detect the Nitrogen content through the colors and tones of the infrared color picture. It will display a 3D model of the real UTM coordinates and their respective elevation with the real color and the reference to the axes.

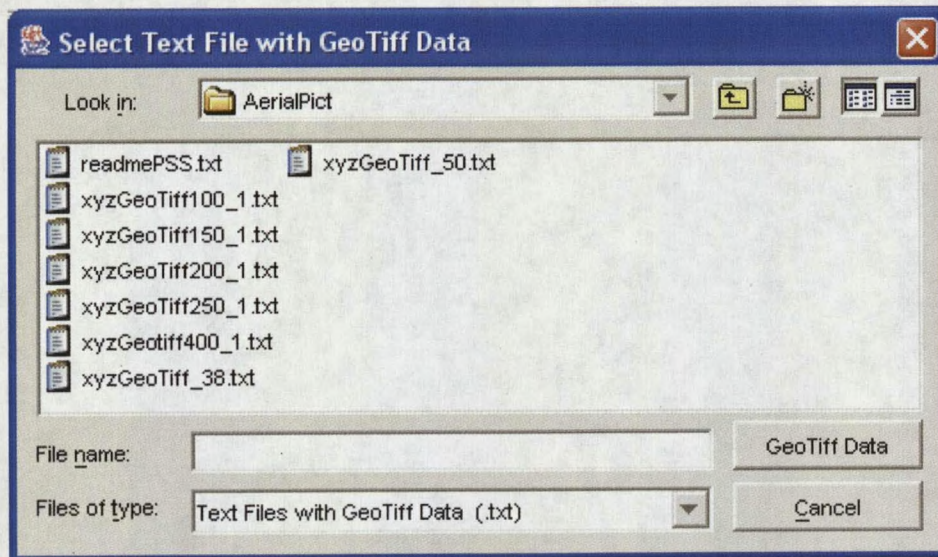
### Creating the Aerial Picture Model

- Execute the button “Aerial Picture.”
- Select the file that contains the data with the position and its color.
  - a. A window titled “Select Text Files with Geotiff Data” will show.



- b. Browse through the folders on that window by double clicking on them.

- c. Select the geotiff data file. The example files are in folder AerialPict, and the names are xyzGeotiff#\_1.txt.
- Execute the button “Geotiff Data.”



### Format of the Aerial Picture Data File

It contains the number of 3D points in the file. The next three lines are the axis and the minimum and maximum values of the UTM coordinates northern for X, eastern for Y and Z for elevation in meters. The next line is the minimum and maximum possible values of RGB (red, green, blue). The rest of the lines are the coordinates of every point and the RGB values and transparency of it. The values X, Y are UTM coordinates in meters of every point in any order.

---

2939  
X 579566 580221  
Y 5408940 5410230  
Z 924.79 945.79  
C 0 255  
579566 5410230 937.58 106 158 110 255  
579852 5410230 937.21 197 255 215 255  
580138 5410230 937.79 66 78 61 255  
579768 5410230 937.41 247 255 255 255  
580055 5410230 937.7 67 87 77 255  
579685 5410230 938.31 255 255 255 255

---

Table 6 First Lines of an Aerial Picture File

### Manipulating the Model

The following manipulations are the same as were used in the Surface Model.

- Rotations are done drawing the model with the left button (the primary button) of the mouse in any direction. This also can be done with the keyboard with the left, right, up and down arrow keys.
- Translations are done drawing the model with the right button (the secondary button) of the mouse to any position.
- Zooming In/Out is done drawing the model with the middle button or the wheel of the mouse downwards or upwards respectively.
- Exaggerations of the elevation of the surface are done by drawing the point on the slider titled "Scale Vertical Axis" and "Elevation Surface" with the left button (the primary button) of the mouse. This also can be done with the keyboard by clicking Tab until that slider is selected and moving the arrow keys.

## Snapshots

The model is a set of points with exaggerated radius, located in the UTM position, and displaying the real color. Figure 13 shows the rotated model of the surface with the real colors and the elevation exaggerated 15 times and the axis reference.

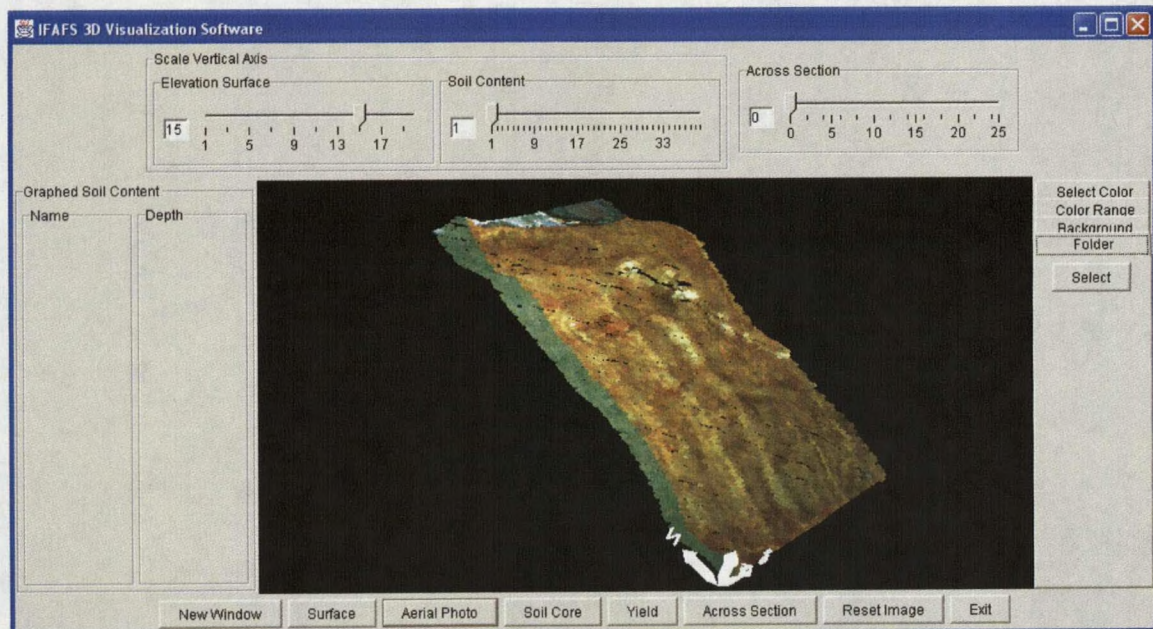


Figure 13 Aerial Picture Model with Exaggerated Elevation of 15 times.

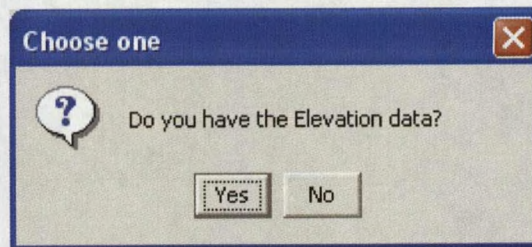
## Soil Core Model

This 3D model offers a more intuitive view of the content of the soil core. The soil core content is analyzed to determine the right amounts of Nitrate prior to crop planting, during early and late crop growth, so it is possible to maximize quality and quantity of yield and minimize expenses. This model shows a wired surface when the elevation file is provided. It also shows stack cylinders of the different levels of data provided in the respective colors accordingly of the proportional concentration of the soil core content

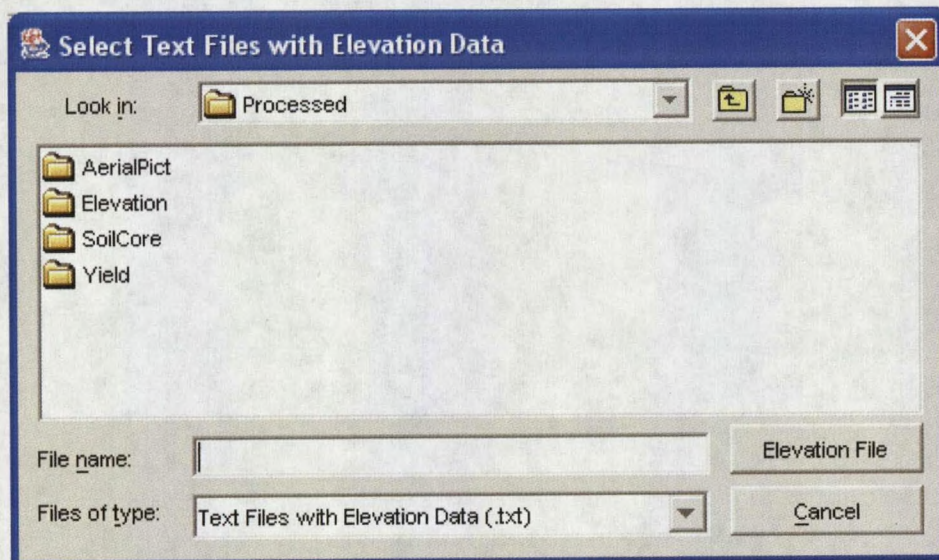
value. The size of the cylinders is initially scaled to 40. The reference to axis is shown as well.

### Creating the Soil Core Model

- Execute the button “Soil Core.”

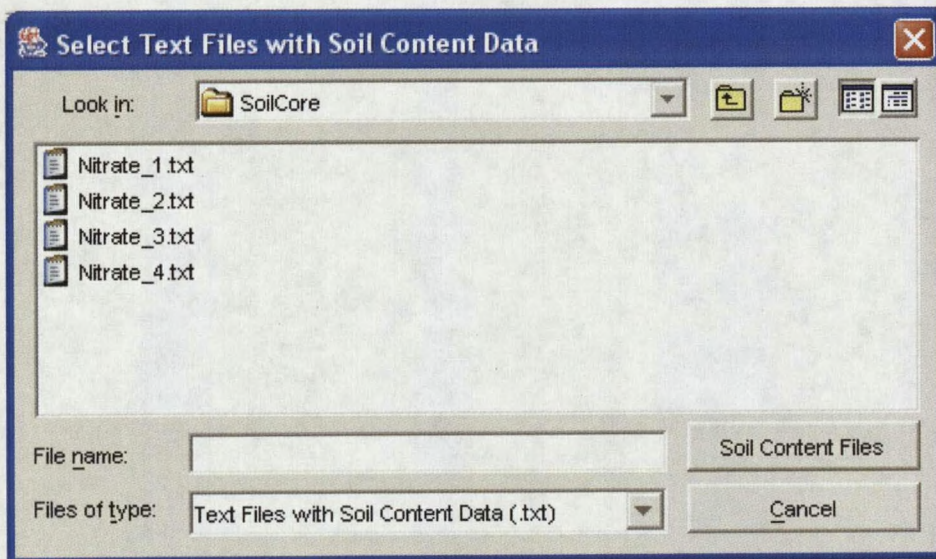


- The application will ask you if you want to show the wire surface with the soil core. Select “Yes” if you have the elevation file for the area that you have the soil core content file, otherwise select “No.”



- If you have it selects the Elevation file.
  - a. A window titled “Select Text Files with Elevation Data” will show.

- b. Browse through the folders on that window by double clicking on them.
- c. Select the elevation file. The elevation example file is in folder Elevation, and its name is Elevation13m.txt.
- d. Execute the button “Elevation file.”



- Select the soil core content file.
  - a. A window titled “Select Text Files with Soil Content Data” will show.
  - b. Browse through the folders on that window by double clicking on them.
  - c. Select the soil core content file. The elevation example file is in folder SoilCore, and its names are Nitrate\_1.txt.
  - d. Execute the button “Soil Content file.”

### Format of the Soil Core File

It contains the number of points to graph. The next three lines are the axis and the minimum and maximum values of the UTM coordinates northern for X, eastern for Y

and Z for elevation. The next two lines are the content minimum and maximum possible values of the soil content measured and the level and the starting and ending depth of the averaged value. The rest of the lines are the coordinates of every point and the corresponding content value. The values are in any order.

---

```

60
x 579722.68 580033.58
y 5409025.81 5410214.53
z 927.052248 945.096408
c 0 180
level1 0 0.15
579722.68 5409025.81 927.052248 36
579795.84 5409025.81 927.591744 26
579887.28 5409025.81 927.954456 26
579978.72 5409025.81 929.44188 12
580033.58 5409025.81 930.402 10
579740.97 5409117.25 929.5638 14
579795.84 5409117.25 930.380664 14

```

---

Table 7 Example of First Lines of a Soil Core Content File

### Manipulating the Model

Most of the following are the same as the Surface Model.

- Rotations are done drawing the model with the left button (the primary button) of the mouse in any direction. This also can be done with the keyboard with the left, right, up and down arrow keys.
- Translations are done drawing the model with the right button (the secondary button) of the mouse to any position.
- Zooming In/Out is done drawing the model with the middle button or the wheel of the mouse downwards/upwards.

- Exaggerations of the elevation of the surface are done by drawing the point on the slider titled “Scale Vertical Axis” and “Elevation Surface” with the left button (the primary button) of the mouse. This also can be done with the keyboard by clicking Tab until that slider is selected and moving the arrow keys.
- Exaggerations of the soil core cylinders are done by drawing the point on the slider titled “Scale Vertical Axis” and “Soil Core” with the left button (the primary button) of the mouse. This also can be done with the keyboard by clicking Tab until that slider is selected and moving the arrow keys.
- Observations of the model in many slices are done by clicking on the button “Across Section.” It will ask the number of slices to divide the model, and if the user want to control the pauses between them.

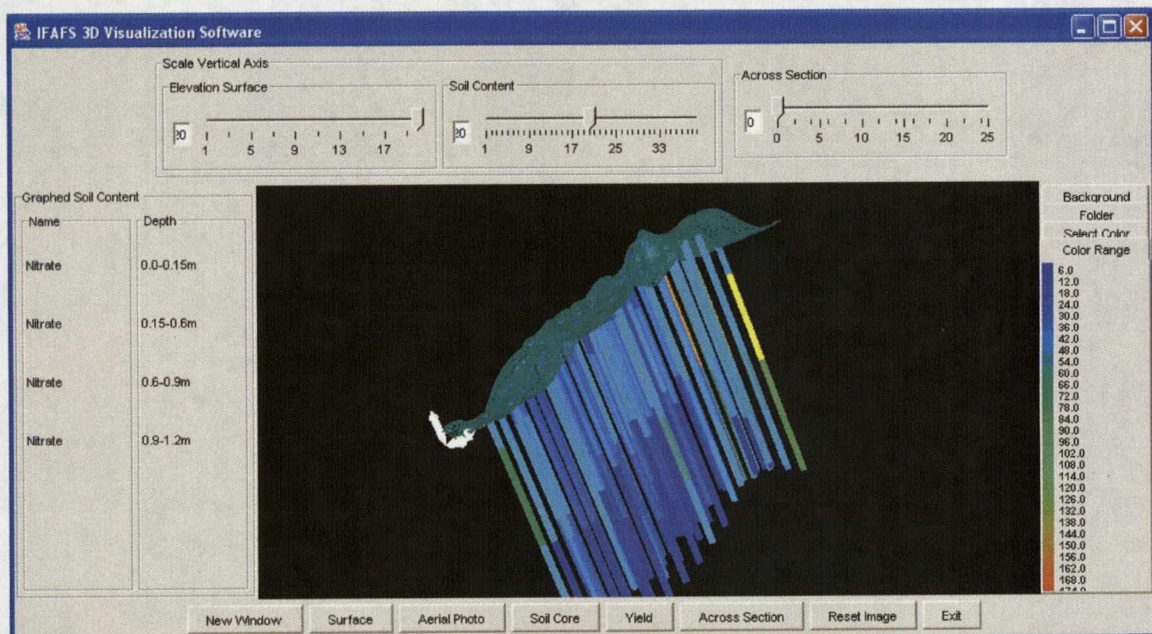


Figure 14 Soil Core Model with Elevation Exaggerated 20 times.

### Snapshots

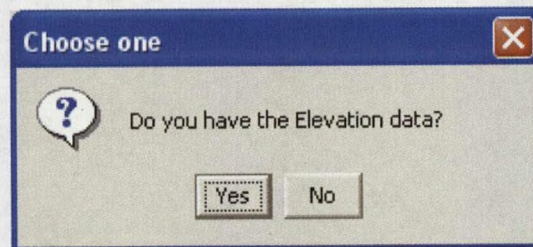
The model of the elevation and soil core content shown in Figure 14 shows the model of the surface and the soil core content with exaggerated elevation of 20 times. Observe that the different levels at which the average was taken is displayed on the left of the application window.

### Yield Model

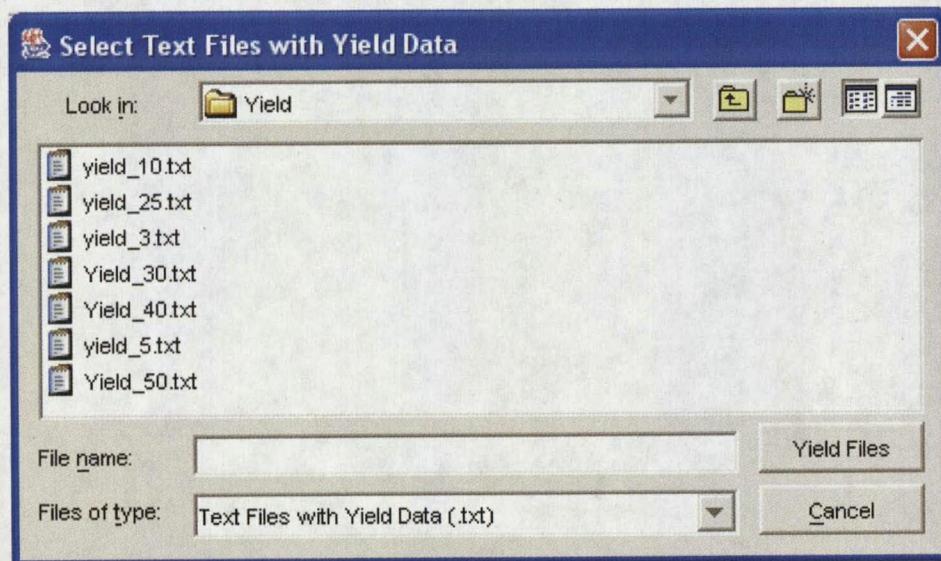
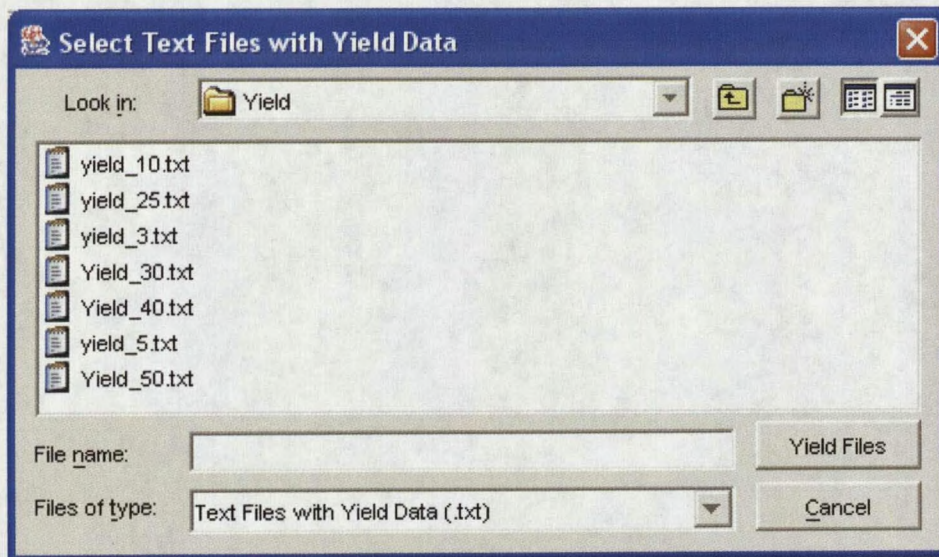
This 3D model offers a better perception of the quality of the crop to help the analysis of it based on the topology of the field. As the Soil Core model, this model shows a wire surface when the elevation file is provided. It also shows circles of the quality of the crop with the respective colors accordingly of the evaluated value of the crop. The reference to axis is shown as well.

### Creating the Yield Model

- Execute the button “Yield.”



- The application will ask you for the elevation file to show the wire surface with the yield. Select “Yes” if you have the elevation file for the area that you have the yield file, otherwise select “No.”



- If you have it select the Elevation file.
  - a. A window titled "Select Text Files with Elevation Data" will show.
  - b. Browse through the folders on that window by double clicking on them.
  - c. Select the elevation file. The elevation example file is in folder Elevation, and its name is Elevation13m.txt.

- d. Execute the button "Elevation file."
- Select the soil core content file.
    - a. A window titled "Select Text Files with Yield Data" will show.
    - b. Browse through the folders on that window by double clicking on them.
    - c. Select the soil core content file. The elevation example file is in folder Yield, and their names are Yield\_#.txt.
    - d. Execute the button "Yield Files."

#### Format of the Yield File

It contains the number of points to graph. The next three lines are the axis and the minimum and maximum values of the UTM coordinates northern for X, eastern for Y and Z for elevation. The next two lines are the content minimum and maximum possible values of the soil content measured and the level and the starting and ending depth cylinder representing the yield. The rest of the lines are the coordinates of every point and the corresponding yield value. The values are in any order.

---

```

8821
X 579564.572 580221.784
Y 5408931.323 5410251.824
Z 924.5359 945.9545
c 0.1 59.2
579722.250000 5408955.500000 926.776428 2.800000
579722.250000 5408961.000000 926.798096 13.800000
579722.250000 5408965.500000 926.735168 22.500000
579722.187500 5408970.000000 926.672668 30.400000
579722.125000 5408975.000000 926.741272 38.200001
579722.000000 5408979.500000 926.708923 44.299999
579721.937500 5408984.000000 926.676086 49.299999

```

---

Table 8 Example of First Lines of a Yield File

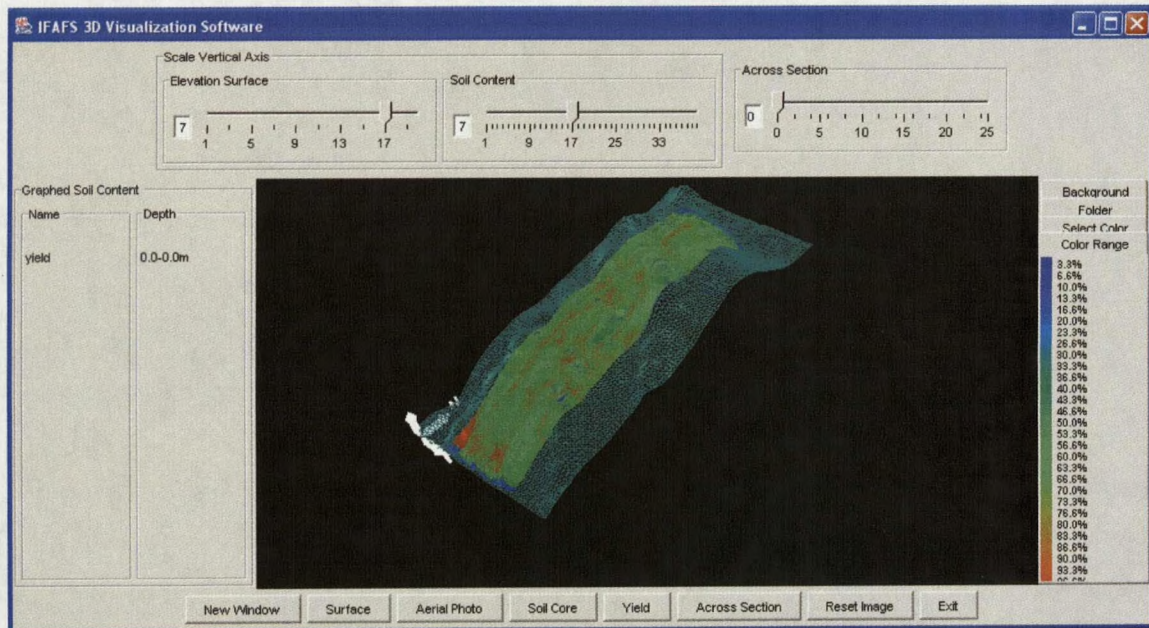


Figure 15 Crop Yield Model on Surface with exaggerated elevation of 17 times

### Manipulating the Model

The following manipulations are the same as for the Surface Model

- Rotations are done drawing the model with the left button (the primary button) of the mouse in any direction. This also can be done with the keyboard with the left, right, up and down arrow keys.
- Translations are done drawing the model with the right button (the secondary button) of the mouse to any position.
- Zooming In/Out is done drawing the model with the middle button or the wheel of the mouse downwards/upwards.
- Exaggerations of the elevation of the surface are done by drawing the point on the slider titled “Scale Vertical Axis” and “Elevation Surface” with the left button

(the primary button) of the mouse. This also can be done with the keyboard by clicking Tab until that slider is selected and moving the arrow keys.

### Snapshots

Figure 15 shows the model of the surface and the crop yield with exaggerated elevation of 17 times.

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