USE OF REMOTE SENSING APPLICATIONS AND VISUALIZATION TECHNIQUES TO AID IN REAL ESTATE MARKETING

THESIS

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Master of SCIENCE

by

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CHAPTER 1

INTRODUCTION

'Time equals money' is a phrase with which most are familiar. Ask any business owner and most will say this phrase states an obvious truth. 'Saving time' is one of the main objectives of this thesis. Searching for a piece of property that matches a specific set of criteria can be a time consuming process. An individual may be searching for a home site or property for recreational use or a developer will be looking for property that meets a specific set of criteria based on the types of homes they want to build. Traveling to view various properties of interest takes up a significant portion of the search process.

With this research, I have demonstrated that current remote sensing technology and visualization techniques can be utilized to significantly cut time spent in searching for suitable properties. The user of these techniques should be able to eliminate a large percentage of properties that look acceptable in a verbal description but may not actually fit their requirements when examined in person. The methodology presented in this thesis will facilitate the user to travel only to properties that most closely match their specifications.

A list of property attributes has been developed to accomplish this task. These attributes are considered to be important in property searches based on personal experience with land purchases. This list has been discussed with three persons involved in the land development or construction industry. At the conclusion of these interviews, it was determined that this list was sound and could be utilized for this thesis.

The next step was to choose a suitable study area. This area needed to be one that did not have a significant amount of development and was accessible, so that ground truthing could be completed. The properties chosen were analyzed using the criteria developed during the interviews. Properties which met the criteria were analyzed using a variety of visualization mechanisms.

- Slope of the landscape for foundation and building costs.
- Color stereoscopic images for viewing topography.
- Vegetation analysis for determining tree types.
- Multi-perspective viewing for visualizing topography and terrain in three dimensions.

The results of the visualization mechanisms listed above are reported in section VI.

- Identification of basic tree types using orthophotos for the data set. Goals for correct identification will be discussed later in this thesis.
- An accurate method for quantifying buildable land surface using remote sensing rather than a physical property survey.
- A method to visualize terrain of many properties in a significantly shorter amount of time than physically viewing them.

The conclusion of this study demonstrates that much of the information gathered through a physical visit to the property can be obtained through remote sensing analysis and visualization.

CHAPTER 2

BACKGROUND LITERATURE

Vegetation Analysis

Trees on a property can be considered either an asset or a liability depending on who is considering the purchase. For example, a builder of expensive homes on larger lots can afford to build structures and driveways around trees (Avent, 2005). Buyers of this type of home will likely expect to have aesthetically pleasing trees kept on their lot. Builders of "cookie cutter" homes (builder slang for homes of similar design and construction in the same subdivision) on smaller lots will often remove trees because it is too expensive to build around them. However, there is still the cost of removing the trees, and when removing trees the builder can be faced with additional issues. Trees that are habitat for endangered species often can not be removed at all. Per local government mandates, when certain tree types are removed, another tree must be planted to replace it elsewhere in the development. Other mandates require penalties to be paid for tree removal, and incentives to be given when trees are retained (American Legal Publishing Corporation, 2005; Harris, 2005). In the scenarios listed above, knowing the tree types on a property would be beneficial for the developer prior to considering a purchase.

Remote sensing can be used in a wide variety of research endeavors. Landscape measurements include position, shape, elevation, color, and temperature (Wilke and Finn, 1996). Within these research areas, remote sensing can provide very specific information such as forest inventory. Wilke and Finn (1996) also list some advantages that remote sensing has over field studies. These include:

1. Provides as much or more detail than field surveys.
2. Accomplishes the above over large areas and can do so repeatedly and at a moderate cost.
3. A wide variety of sensors are available some of which detect details not seen by the human eye.

For this study the speed and cost advantage is of paramount interest. The user is able to reject unsatisfactory areas quickly and spend time focusing on areas that meet their criteria.

There are a number of reasons why tree types can be differentiated through remote sensing. The primary reason is differing levels of greenness. Different plant species will have varying levels of chlorophyll that will affect the greenness of the plant (de Boer, 1993). The structure of the vegetation will cause differences of reflection (de Boer, 1993). In this study, Live Oaks and Ashe Junipers (Fig. 1), which are the predominant species in the study areas (McMahan, 1984), have a very different leaf structure and also show a significant difference in green reflectance between them.

Woodwell (1984) states that CIR (**C**olor **I**nf**R**ared) is more effective than black and white Panchromatic at differentiating species of trees. Woodwell also suggests that CIR is more effective than normal color at differentiating grass, forbs, and shrubs. However, there is no mention of testing between CIR and normal color for differentiating tree types. Imagery in both CIR and normal color was available for the study areas

Figure 1. Live Oaks and Ashe Junipers in study area show a large difference in green reflectance.

discussed in section III. Since both are available, it was of interest to determine which differentiates tree types the best.

Color Stereoscopic Cartography

The color stereoscopic effect is a phenomenon where colors in a spectral sequence are perceived to be at varying depths or distances depending on their wavelength. The effect has been well documented over the last 100 years, but only recently has been applied to cartography (Eyton, 1990).

The color stereoscopic effect is introduced to a topographic map by assigning colors in a spectral sequence to the changing relief in a topographic map (Fig. 2). When viewed with holographic glasses (Chromadepth 3-D glasses) the relief can be seen in depth. Eyton (1990) showed that this effect can be enhanced by the addition of elevation contour lines and hill shading. Klier & Eyton (2004) provide a method for further enhancing the effect by applying a logarithmic scale to the elevation data. These enhancements have been utilized for this thesis.

Slope Analysis

Slope is technically defined as the rate of change of elevation with respect to distance. Eyton (1991) describes how a slope magnitude data set can be derived from a Digital Elevation Model (DEM) using Terra Firma (Eyton, 2004). Slope of a given landscape is important to consider when choosing a building site. It is more expensive to build on sloped landscape than it is to build on flat land. Most of this expense is from the increased mass of the slab to account for the slope (Klier, 2005).

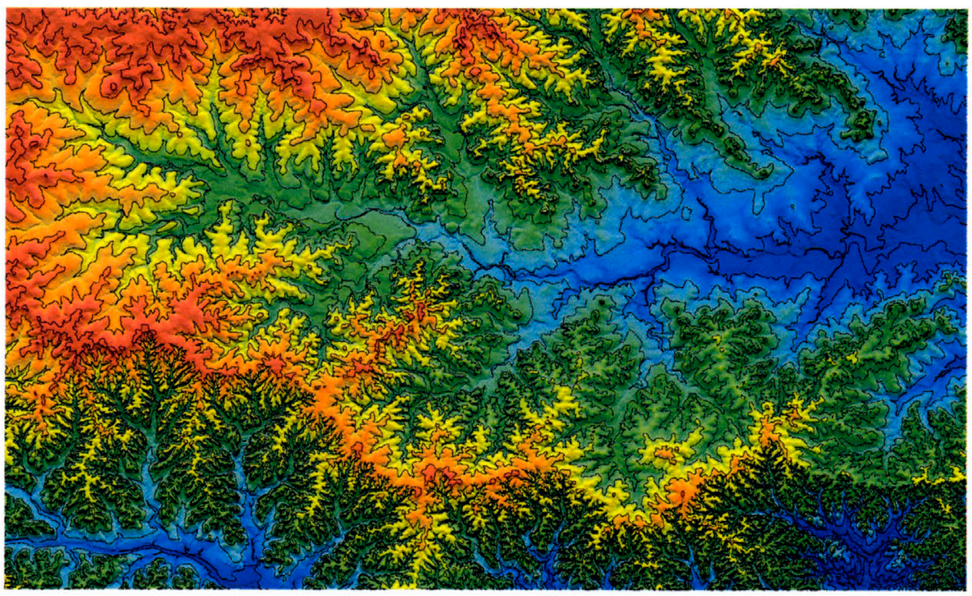

Figure 2. A color stereoscopic map (with hillshading and topographic lines) of the Hill Country near Fredericksburg, Texas. Higher elevations are shown as red and lowest elevations as blue. Chromadepth 3-D glasses are required to view the full stereoscopic effect. Scale 1:900,000

When producing the slope map, a decision was made either to use the actual slope measurement in degrees for representation in the legend, or to accompany the class limits with a verbal description. Young (1972) gives four examples of classification schemes using verbal descriptions of the terrain. Examples of some of these terms are "flat", "gently sloping", and "steep". For this research, class limits and class descriptions were determined after the conclusion of the interviews and are given in section V.

Multi-Perspective Visualization

While contour maps and color stereoscopic effect maps give the user a great amount of data about the terrain, they are still only from one perspective, generally looking down from above. Multi-perspective visualization, also known as perspective mapping, is created by overlaying an aerial or satellite photograph over a DEM of the same area. Using a PC and software such as 3Dem (Horne, 1999), the user then has the ability to place themselves in any perspective on or above the terrain.

One can imagine many potential uses for this technique. One obvious use is to show a potential buyer what can be seen from a particular point of view. For example, whether there is a view of a lake or valley would be useful in choosing a building site.

Early forms of this technology used simple wire-frame computer graphic models. After the eruption of Mount St. Helens, the U.S. Geological Survey produced this type of model to show pre and post eruption views of the mountain (U.S. Geological Survey, 1980). With the speed of computers today, a user can have a very realistic, virtual perspective view complete with trees and landscapes. This virtual reality has the potential to produce environments that are essentially indistinguishable from reality (Ludwig, 1996).

CHAPTER 3

STUDY AREAS

The study areas require a specific set of attributes to allow for the types of analysis I have utilized. These include:

1. Availability of LIDAR (**LI**ght **D**etection **A**nd **R**anging) coverage. (LIDAR data is used in this study to produce a high resolution DEM).
2. Availability of Air photo or satellite photo coverage in true color and CIR.
3. Accessibility for ground truthing.
4. Be relatively undeveloped. (Some houses on larger lots would be acceptable).

Due to current limited coverage of LIDAR, it was not be possible to find one single property that met all of the requirements. The areas covered by LIDAR were not accessible for ground truthing. However, the analysis that required the LIDAR data was not dependent on ground truthing. This being the case I used an area with LIDAR coverage for the slope analysis and another area for the vegetation analysis. The color stereo and 3D perspective analysis could be performed on either area.

Area 1 (Fig. 3) is approximately 3.5 kilometers west of downtown Austin. This area has LIDAR coverage, is relatively undeveloped, and has varying relief. Area 2 (Fig. 4) is approximately 40 kilometers west of Austin. The terrain is similar to Area 1, it has air photo coverage in both true color and CIR, and is accessible for ground truthing.

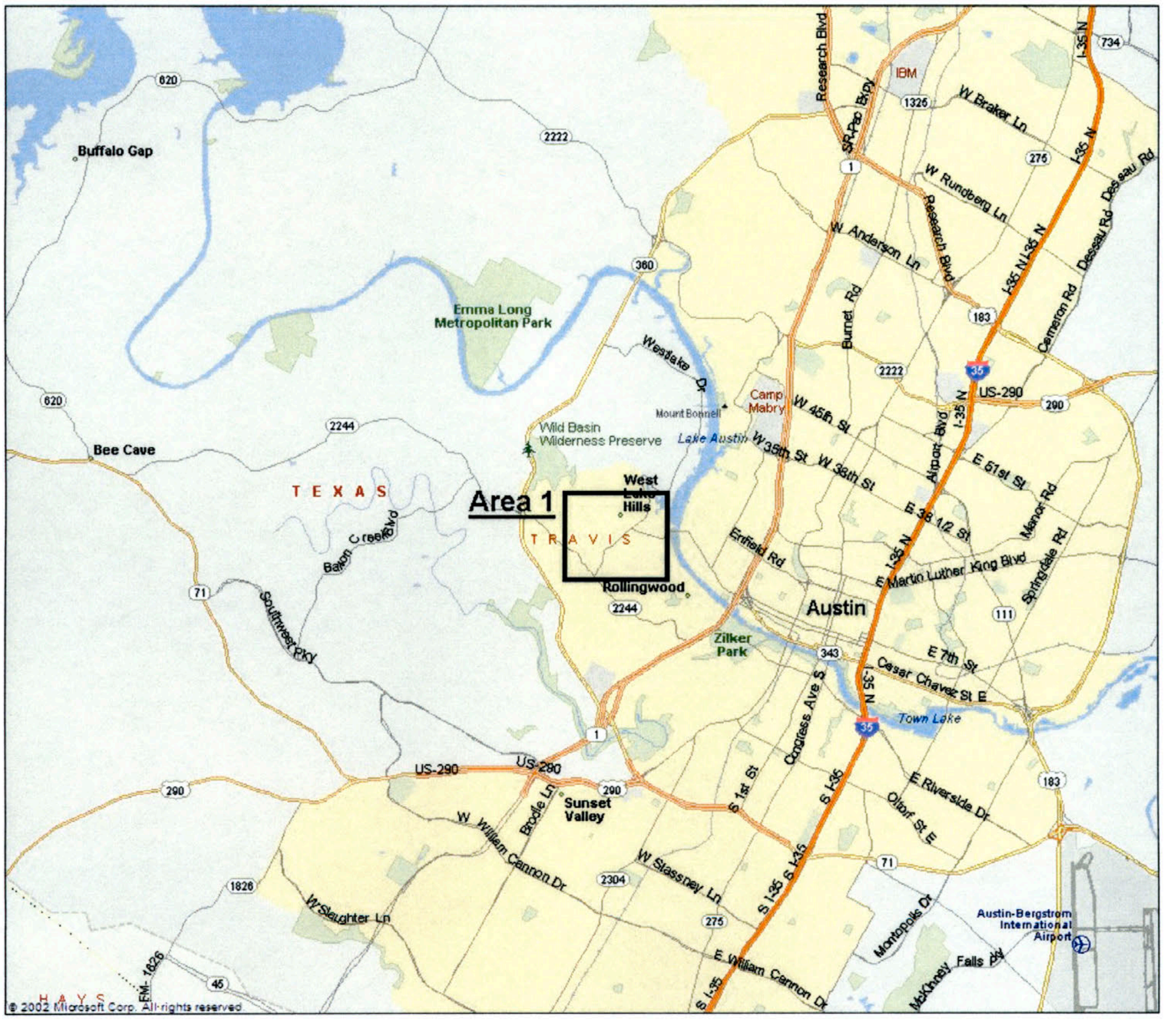

Figure 3. Rectangle indicates approximate location of study area 1 located 3.5 kilometers West of downtown Austin. Scale 1:325,000. (Microsoft, 2002)

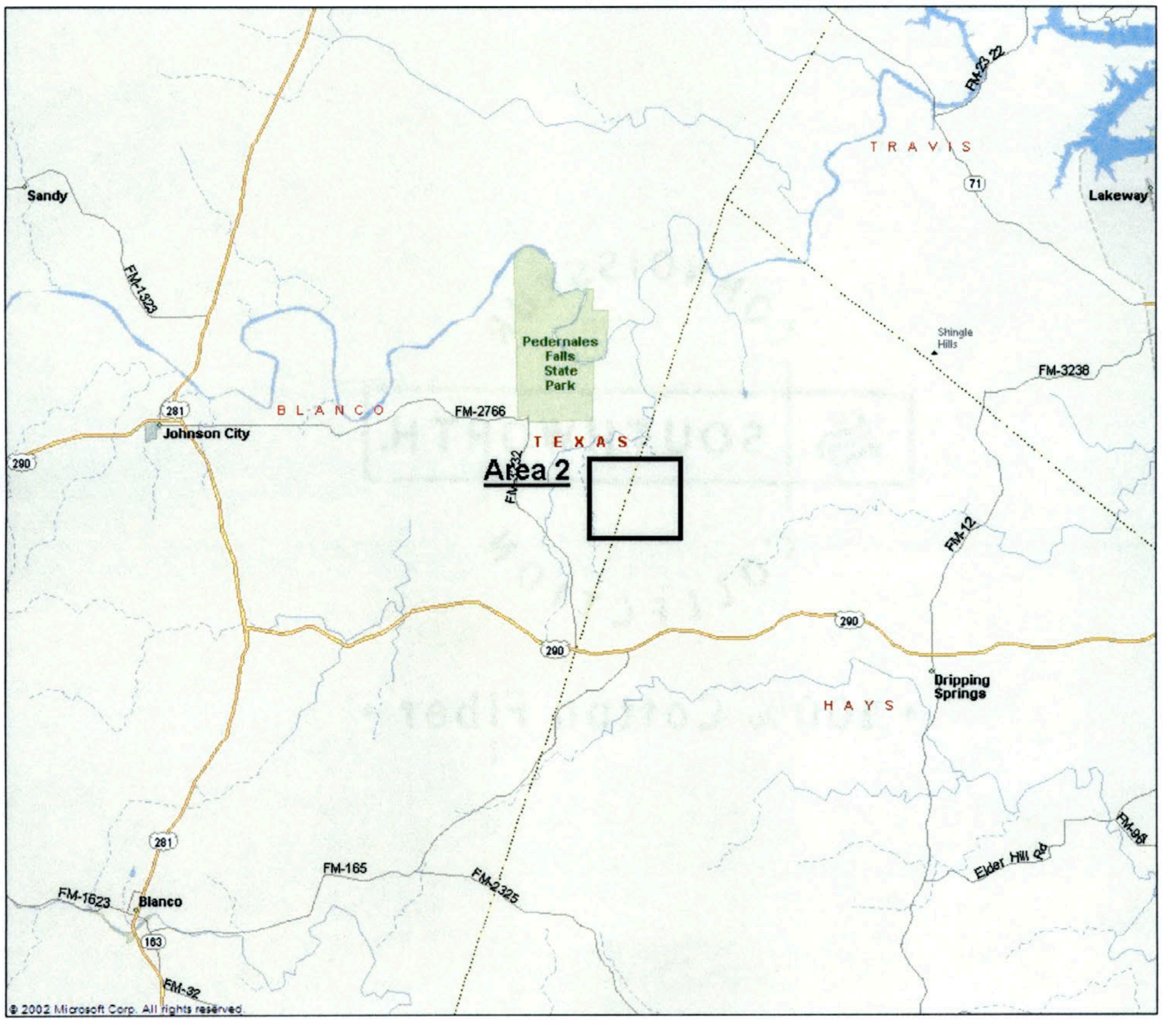

Figure 4. Rectangle indicates approximate location of study area 2 located 40 kilometers West of downtown Austin. Scale 1:500,000. (Microsoft, 2002)

Area 2 also has a mix of Live Oaks and Ashe Junipers, which makes it suitable for the vegetation analysis.

CHAPTER 4

DATA

LIDAR data utilized for the application in Area 1 were collected on August 17th and 18th, 2000, for the Bureau of Economic Geology at The University of Texas. A 1.5 meter resolution DEM was extracted from this data. A 30 meter resolution DEM of the same area was obtained from the U.S. Geological Survey NED database.

The normal color orthophotography was available for download from the Capitol Area Planning Council website (Capitol Area Planning Council, 2005). The imagery was obtained in February of 2002 from an altitude of 5,500 meters with a resulting resolution of 0.6 meters.

The CIR orthophotography was available for download from the Texas Natural Resources Information System website (Texas Natural Resources Information System, 2005). The imagery was gathered in 1996 by VARGIS of Herndon, VA, for the Texas Orthoimagery Program (TOP). This imagery has a resolution of 1 meter.

CHAPTER 5

METHODOLOGY

Vegetation Analysis

When I was searching for a property, one personal requirement was to have a significant number of Live Oaks. Real estate listings would often only use the term "wooded" to describe the tree cover. I spent a significant amount of time driving to properties to find that they did not meet my requirements. For this reason and the reasons discussed in section II, a vegetation analysis can be a valuable tool for choosing suitable properties.

The vegetation analysis was performed using ERDAS Imagine. Both CIR and true color data sets were processed using supervised training field classification, unsupervised training field classification, and as a NDVI (Normalized Difference Vegetation Index) monochrome image. Ground truth points gathered with a Magellan Meridian Gold GPS were overlaid on a map of the results. The percentage of correctly identified trees was tabulated from this map. The acceptable level for correct identification depends on the intended use of the property. In some areas, certain species of trees being removed that have a trunk size of 19 inches in diameter or larger need to be replaced with another tree in a new location (Avent, 2005). While this method will not identify trees with a certain trunk size, it will identify where trees of a specific species are located. In this case, an extremely high level of accuracy may not be needed since a surveyor may only need to get a general idea of where to look for this species of tree when determining the trunk diameters. There are other cases where a higher level of accuracy may be needed, such as finding tree species that are habitat to endangered species.

Since there is no real correct answer to the question of 'what is an acceptable level of classification', I have simply shown the method is accurate up to a certain point. This threshold will likely be acceptable for some circumstances but not for others.

Color Stereoscopic Effect Cartography

Visualizing terrain from a topographic map is second nature to a person that works with these maps on a regular basis. For someone not used to this type of data it can be a difficult task. A color stereoscopic effect map gives those users a three dimensional image of the terrain as if they were looking down from above.

Using Terra Firma (Eyton, 2004), a continuous color terrain map was produced. First a relative radiance file was produced from the DEM. By inputting the solar azimuth and solar elevation, a hillshaded relief map was derived from this file. An edge contour map was created from the DEM with a given contour interval. The final step was to create the continuous color terrain map with the edge contour and hillshade maps as an overlay. The rendition is a linear spectral sequence of 1021 colors ranging from blue for low terrain through red for high terrain. The relief effect is enhanced using holographic optical element glasses sold under the trade name of Chromadepth.

Slope Analysis

Since building on a slope is more expensive than building on flat land, a property should be surveyed to determine how much area is within the required slope specifications for determining cost of building. Using Terra Firma (Eyton, 2004), a slope map was created from a DEM extracted from the LIDAR data. Using the same method, a slope map was created from the USGS 30 meter DEM. The resulting maps are classed color maps with slope in degrees measuring from 0 degrees to a maximum of 15 degrees. The maximum of 15 degrees was determined through interviews of a builder, land developer, and home designer (Avent, 2005; Harris, 2005; Klier, 2005). Anything beyond this slope maximum is considered un-buildable and was colored black. The useable land surface area between 0 and 15 degrees was further split into three categories which are 0 to 7 degrees, 7 to 10 degrees, and 10 to 15 degrees. What is considered a useable slope class interval varies depending on the types of homes to be built. High value homes can be built on a high degree of slope since the added cost of the slab does not impact the overall cost of the home as much as a low cost home (Harris, 2005). The area from 0 to 7 degrees is useable for any type of home. This will often consist of low cost homes which are generally built at 3 to 5 units per acre (Avent, 2005). Slopes from 7 to 10 degrees are useable for high value homes but limited for low value homes. Slopes from 10 to 15 degrees are useable for high value homes only.

Clustering of the useable slope areas was also considered. A property that shows 75% useable surface but is mostly clusters of 1 acre or less is not useable for a high value subdivision building on lots of 1 acre or larger. While there are statistical methods for automatically calculating cluster size, I believe a simpler method would serve this purpose better. For this step, a grid of 1 acre squares was overlaid on the slope map. This provides a potential builder or developer a very quick and easy method to determine whether or not there is enough clusters of useable building surface.

The final step was to determine the overall area of useable surface. My interviews have determined that an acceptable level of buildable surface is a moving target, meaning it will change depending on the type of development being planned (Avent, 2005). The method presented is only capable of determining the amount of useable area, and the average cluster size.

Multi-Perspective Visualization

This technique allows a user to place themselves anywhere on or 'above' a property for a three-dimensional perspective view. This allows the user to visualize the surroundings in a way that is more familiar, in three dimensions rather than two. For those who have trouble visualizing topography from a topographic map, this method will provide the perspective they are missing.

Utilizing Terra Firma (Eyton, 2004), a DEM and aerial photograph of the same location were registered to each other. The registration is necessary so that images in the photo exactly match their respective areas in the DEM. The final step is to drape the photo over the DEM. This was accomplished using imaging software called 3Dem (Horne, 1999). Once this drape is complete, the user can use 3Dem to place the viewer anywhere on, above, or around the landscape.

CHAPTER 6

ANALYSIS

This work focuses on saving tıme and this was accomplished by utilizing technological advances in computers, software, and remotely sensed data. Saving time has always been a basis of advancement in modern society. By utilizing the assembly line method of construction, Henry Ford produced an automobile faster and at less cost than anyone before. This single advance initiated a new era in manufacturing. While progress in remote sensing as applied to real estate are not at the same level as the development of the assembly line, the above example was given to illustrate how a relatively simple concept can lead to many new concepts.

Vegetation Analysis

Working with the data sets and methods listed in sections IV. and V., I found that using the color infrared imagery with supervised traınıng field classification yielded the best results when compared with the other methods mentioned in the previous section. Figure 5 shows study area 2 classified with this method and data set. Live oaks are shown as blue and ashe junipers as red. Yellow and black dots show ground truthed locations for live oaks and ashe junipers respectively. Table 1 shows the results of the ground truthing. Identification of live oaks was well above my minimum expectation of 75%. Out of 38 trees detected as live oak, only 7 were actually other species. This shows that

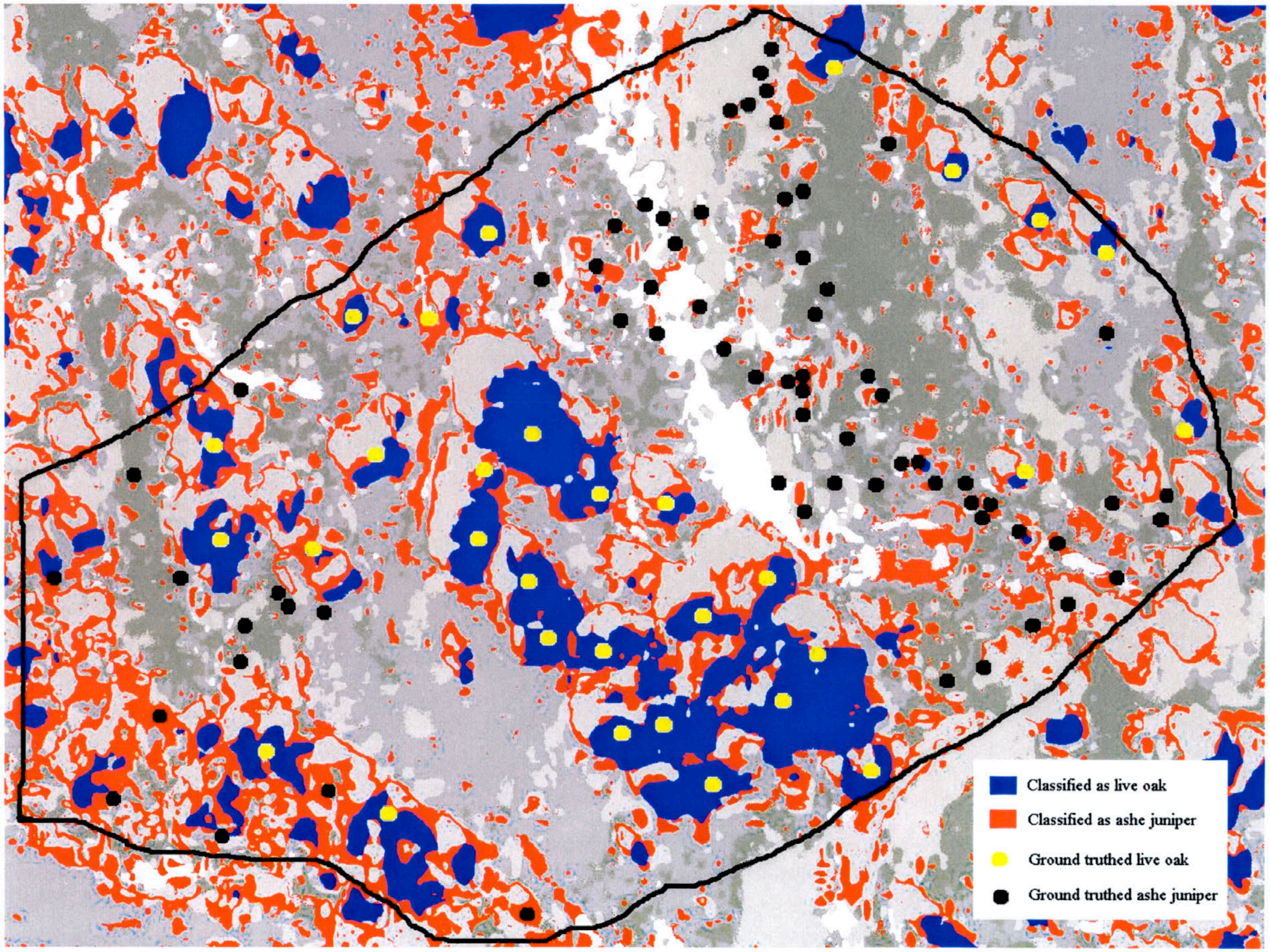

Figure 5. Supervised training field classification of area 2 created with color infrared imagery.

Table 1. Results of Vegetation Survey

Number of trees identified as live oak	38
Actual number of live oak trees	31
Percentage of correct identification	**82%**
Species of trees mis-identified as live oak	
Ashe Juniper	1
Cedar Elm	6

live oaks can be accurately differentiated from ashe junipers using this method. Ashe juniper detection was less successful. Many of the ashe juniper canopies at the study area measured less than the 1 meter resolution of the imagery. This resulted in many ground truth points not coinciding with a detected tree. Also, the accuracy of the GPS unit is approximately 3 meters (plus or minus). This, along with tree canopies measuring below 3 meters, resulted in the ground truth points missing some of the detected trees. There was also a large amount of ground clutter misidentified as ashe juniper.

Overall, the results of this visualization mechanism met he goals of this research. In most cases live oaks are the type of tree a developer would be interested in. However, there are some instances where detection of ashe junipers would be important, such as areas where endangered species use them for habitat. There was no attempt to differentiate between live oak and other tree species besides ashe juniper. Study area 2 does not contain a large number of other tree types. Some of the misidentified live oaks turned out to be cedar elms. Further study would need to be done to differentiate these types. Since these species are of similar greenness and leaf structure it is likely that high resolution imagery and/or multi-spectral imagery would be required.

Showing that the vegetation detection method works solves only part of the problem. There must also be a savings of time for this method to be viable. For cost estimates, a nominal rate of $35 per hour was utilized for both surveying and remote sensing tasks. This cost was based upon a typical rate paid for those job types. Table 2 shows a general comparison for the two approaches. The time spent on the property for the survey is based upon the time I spent ground-truthing with the GPS. Time spent on

Table 2. Estimated Costs for Vegetation Survey.

Estimated time spent for physical vegetation survey	8
Estimated hourly cost of physical survey	$35.00
Estimated cost for physical survey of area 1	**$280.00**
Estimated time spent for remote vegetation survey	4
Estimated hourly cost of remote survey	$35.00
Estimated cost for remote survey of area 1	**$140.00**

the remote sensing analysis is based on the time spent retrieving the online data and running the analysis that produced the best results.

Table 2 shows a two times savings in time and money using a remote survey to detect live oaks. Differentiating other tree types would add to the cost because higher resolution or multi-spectral imagery would likely be needed to accomplish the task. However, for most of the applications discussed in this thesis, the presented method was adequate.

Color Stereoscopic Effect Cartography

There are two main advantages to using a color stereoscopic effect map to view topography. First, it gives the user a three-dimensional view of the terrain as can be seen in Figure 6 (use the included Chromadepth glasses for full stereoscopic effect). This is advantageous for those not used to reading topographic maps. Second, it gives the user the ability is view the terrain of many potential properties in a short amount of time. Again, the question to be answered is whether this method can be used to save time and money. The most significant savings would come from the reduced need for travel. In this case, I am assuming the user would use the color stereoscopic effect method to eliminate some properties from consideration based upon those properties having terrain that is undesirable. Table 3 shows the costs associated with viewing 5 properties using color stereoscopic effect maps versus a physical visit. I made an assumption of 10 miles between properties. Since there was no way to put a price on the time spent by the user in viewing the properties I let this value be the same as the hourly rate for the remote sensing analyst and surveyor.

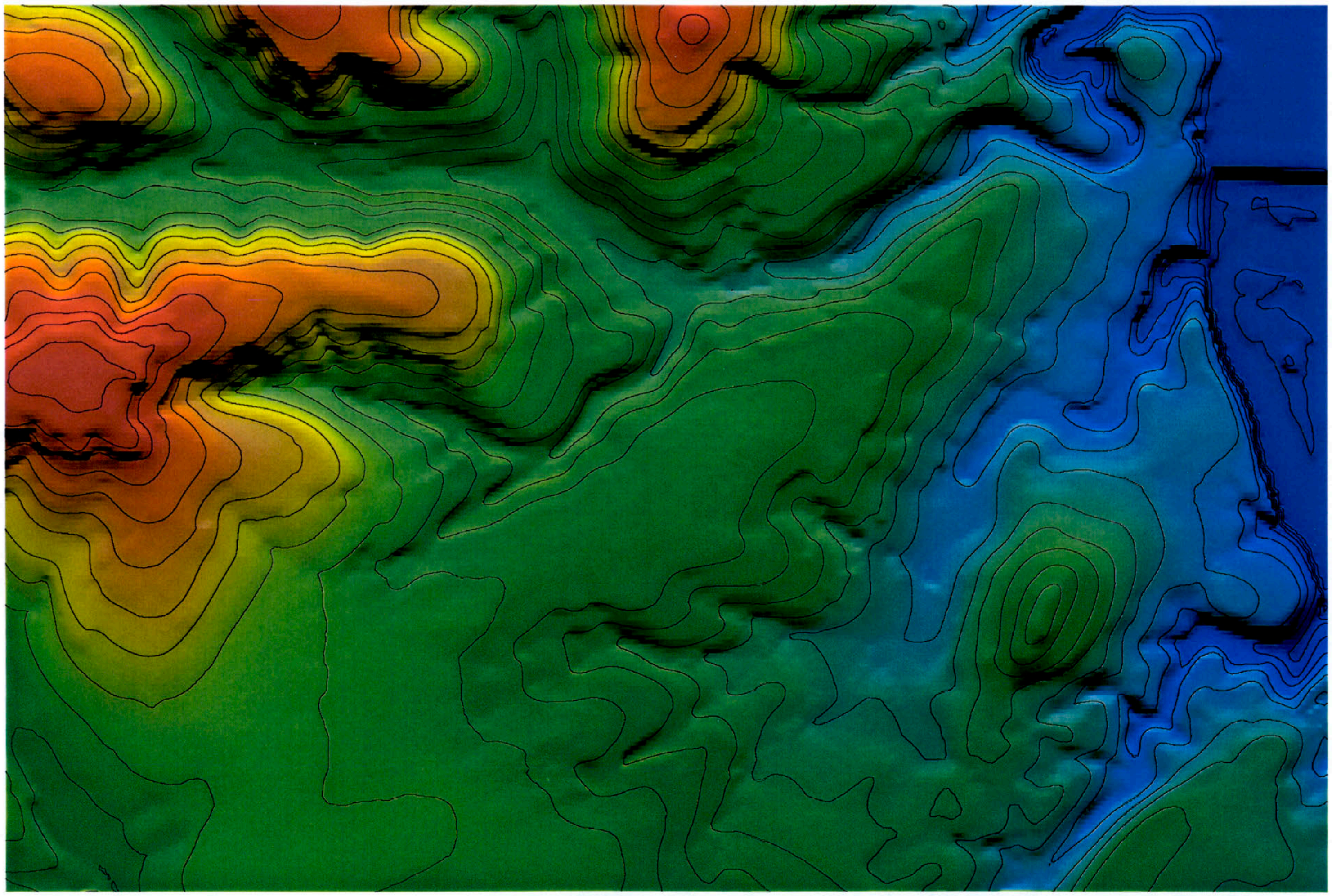

Figure 6. A color stereoscopic effect map of study area 1. Use the included chromadepth glasses for full effect.

Table 3. Estimated Costs for Creating Color Stereoscopic Maps Versus Physically Visiting Properties.

Estimated time spent for visiting 5 properties*	4
Estimated hourly cost of physical survey	$35.00
Estimated fuel costs**	$7.00
Estimated cost for visiting 5 properties	**$147.00**
Estimated time spent creating 5 color stereoscopic maps	1.5
Estimated hourly cost of creating color stereoscopic maps	$35.00
Estimated cost for creating 5 color stereoscopic maps* **	**$52.50**
* Assuming 20 minutes travel to each property and 30 minutes spent at each property.	
** Assuming 10 miles to each property, $2.75 per gallon fuel cost and 20mpg.	
*** DEM's for the entire United States are available at no charge so no costs were added for their creation.	

This method also shows a significant savings in time and money. While it is not intended to completely replace the process of physically viewing a property, it does offer an excellent way to eliminate those that are obviously undesirable.

Slope Analysis

Of the four type of analysis being introduced, I would consider this to be most important. A property must have enough area at or below a given slope to be economically viable for a proposed type of development.

After creating slope maps using both the 30 meter resolution NED data and the 1.5 meter resolution LIDAR data it was determined that the NED data produced a more useable map. The LIDAR offered too much detail as it detected elevations of individual trees and buildings. On the slope map this showed as noise or ground clutter. Figure 7 shows a classed color slope map of study area 1 produced from the NED data. One can quickly see there is a large amount of surface area that falls between 0% and 10% slope. This is useable for either low or high cost homes. To aid in showing how much area is covered by each class, the map shown in Figure 8 was produced. This is the same classed color slope map with a 1 acre grid pattern overlay. This is a quick and simple method to quantify the areas of interest and to show how these areas are clustered.

Statistical software can be utilized to calculate average cluster size and overall size of a given slope classification. However, there is a quick and simple method that should be considered. Figure 9 shows the classed slope map with grid overlay. The clusters of 0 to 7 degrees of slope with at least two adjoining 1 acre squares have been

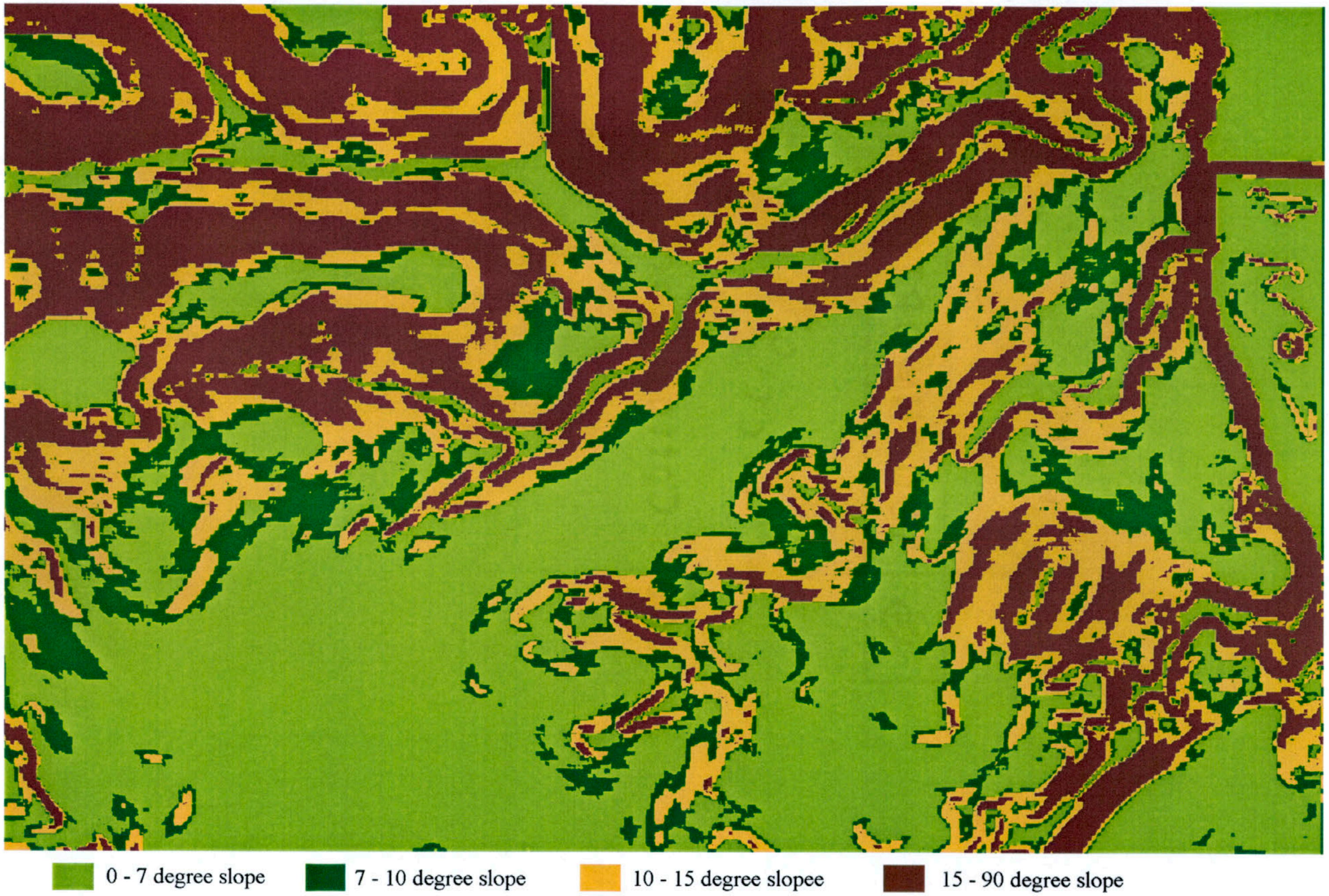

Figure 7. Classed color slope map of study area 1.

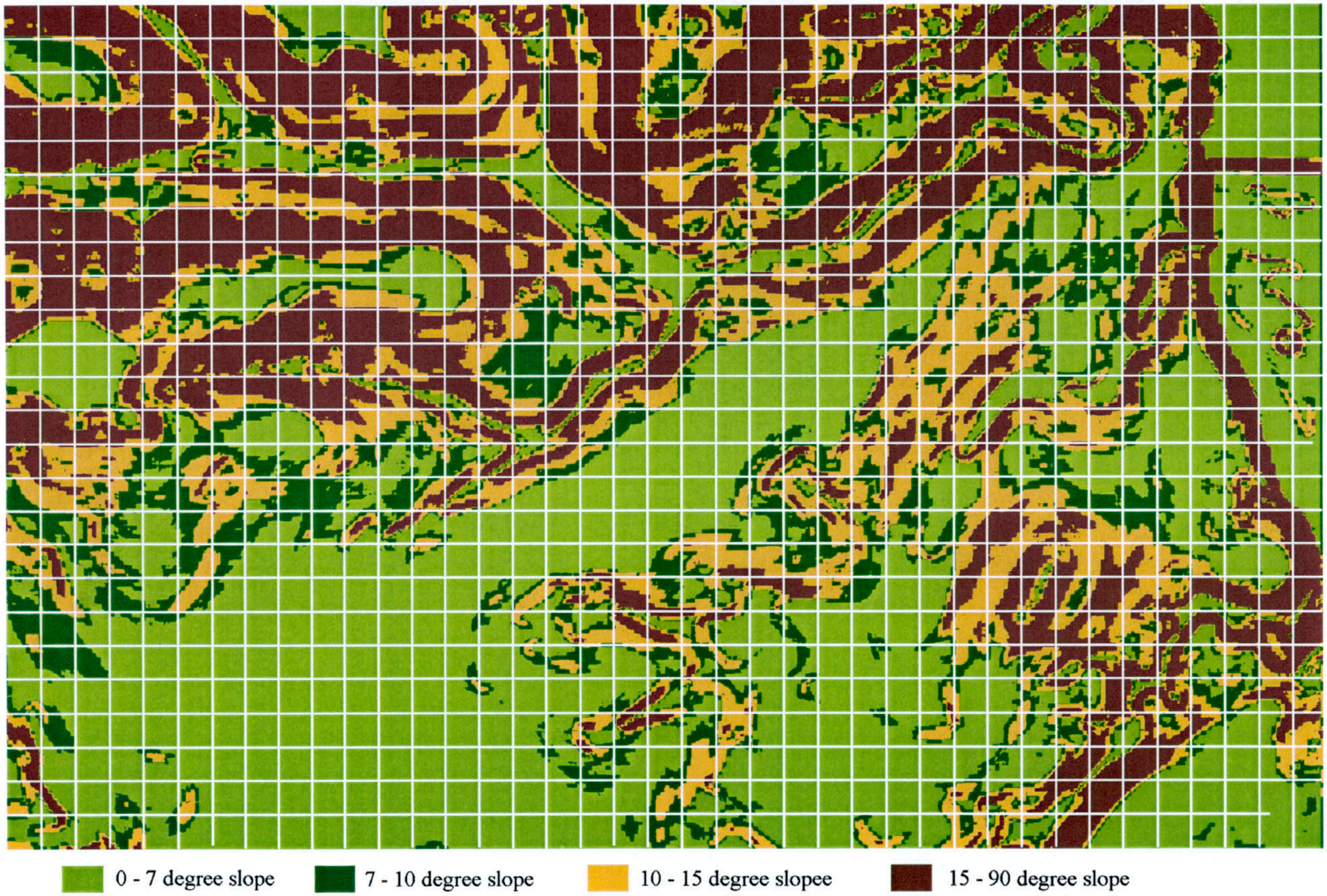

Figure 8. Classed color slope map of study area 1 including 1 acre grid overlay.

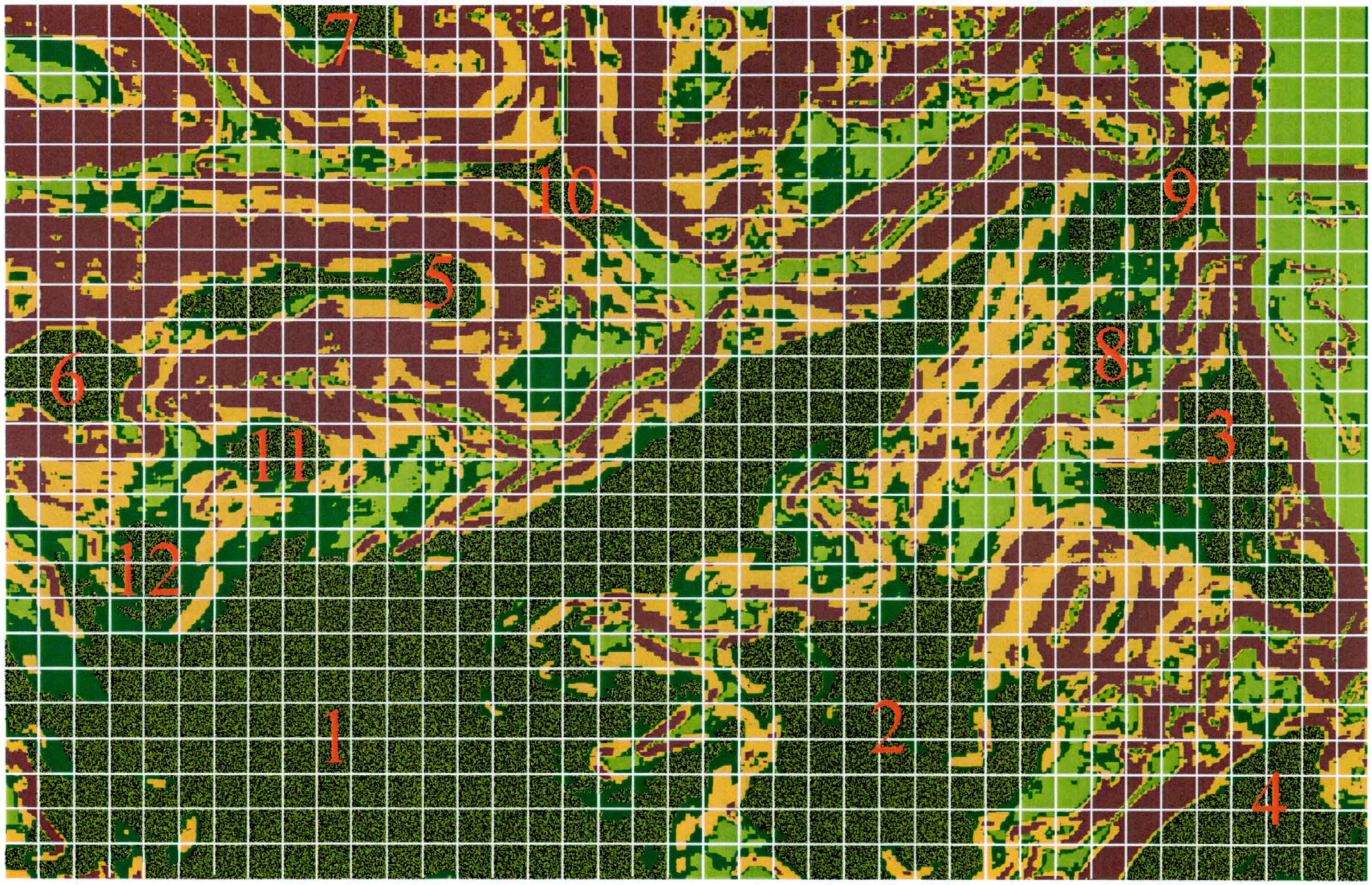

Figure 9. Color classed slope map with 0 to 7 degree slope clusters highlighted and numbered.

selected and assigned a cluster number (the area in the upper left was omitted since this is part of the lake). By counting the number of full 1 acre squares in each cluster a reasonable estimate of cluster size can be determined. After all clusters are counted the average cluster size can be calculated. This method may seem overly simple, but it is quick and effective. In this example, the total area with 0 to 7 degrees of slope is approximately 248 acres and the average cluster size is approximately 21 acres.

Since some development has taken place in study area 1 it is of interest to illustrate how development patterns fit the slope map. Figure 10 is a map created by combining the aerial photograph with the slope map. This was accomplished by applying the photographic image to the red channel and the slope map to the blue and green channels (producing a cyan overlay). This image confirms that higher density construction is more prevalent on the lower slopes while the larger multi-acre lots appear more on the higher slopes.

Table 4 shows an estimated cost of producing the slope map versus the estimated survey costs. Once a property is to be purchased, a physical survey will always be required. This method introduces a way to narrow the search field for properties with useable slopes.

Multi-Perspective Visualization

The benefits and cost savings provided by this mechanism are very similar to that of color stereoscopic effect cartography. Both methods allow the user to visualize terrain in three dimensions. The color stereoscopic map only has one perspective, which is looking straight down from zenith or directly above. Multi-perspective visualization allows the user to move their perspective anywhere on, around, or above the terrain.

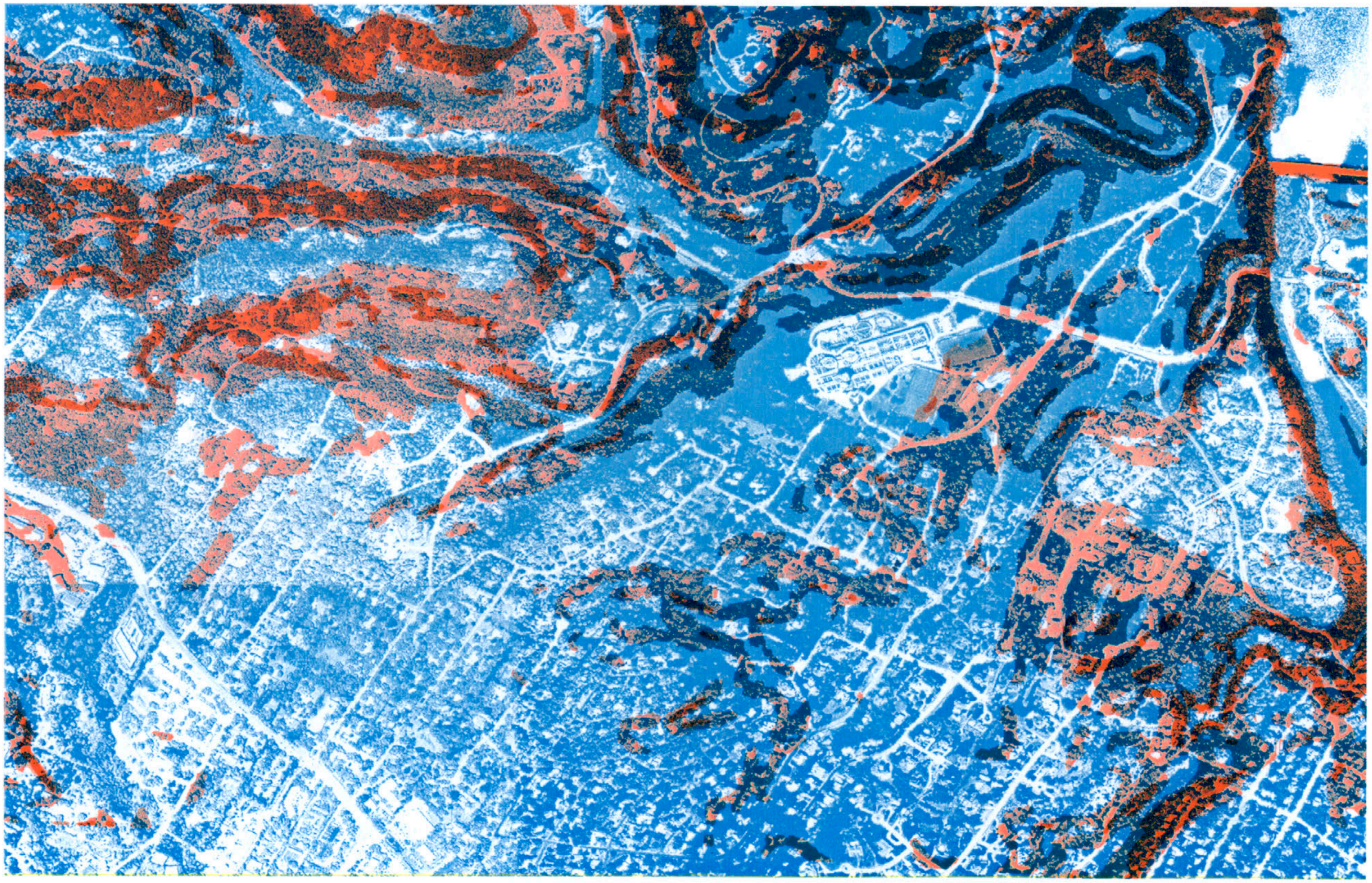

Figure 10. Combination of aerial photo and slope map illustrating development density on various degrees of slope.

Table 4. Estimated Costs for Physical Survey Versus Creating Slope Map.

Estimated time spent for physical survey	8
Estimated hourly cost of physical survey	$35.00
Estimated cost for physical survey of area 1	**$280.00**
Estimated time spent creating slope map	3
Estimated hourly cost creating slope map	$35.00
Estimated cost for creating slope map	$105.00

Using this method, two maps were produced; one from the 1 meter resolution LIDAR data and the other from the 30 meter resolution NED data. The LIDAR data is desirable due to the higher resolution which is fine enough to detect the elevation of trees and buildings but does present some problems. Registration of the photography to the DEM becomes more difficult making the registration process less forgiving. Roads and buildings must line up exactly or the resulting image does not look correct. Figure 11 shows a portion of study area 1 that has been registered using the LIDAR data.

Figure 12 shows the same portion of study area 1 but this time registered to the NED data. This image does not have the fine elevation resolution displayed in Figure 10 however, it does offer an image that is much easier to analyze. Trees, roads, and buildings are more distinguishable in this image (Fig. 11). The LIDAR based image may be useful if tree and building elevations are important, but for most uses the NED based image would be better. The costs involved in producing these images are shown in Table 5.

Figure 11. 1.5 meter resolution DEM with draped normal color aerial photograph.

Figure 12. 30 meter DEM with aerial photograph drape.

Table 5. Estimated Costs for Multi-perspective Visualization Map.

Estimated time spent for physical survey	8
Estimated hourly cost of physical survey	$35.00
Estimated cost for physical survey of area 1	**$280.00**
Estimated time spent for multi-perspective visualization map	2
Estimated hourly cost for multi-perspective visualization map	$35.00
Estimated cost for remote survey of area 1	**$140.00**

CHAPTER 7

CONCLUDING COMMENTS

Automation of a process will most often produce results faster and less costly than manual labor. Savings in money may not always be seen immediately due to the initial investment in the technology. Over time, these initial costs are reduced as a technology often becomes more readily available at lesser cost. Accuracy is another factor to be considered in automation. Initial accuracy of automation may be lower than manual labor but should be expected to increase as the technology improves. I would estimate that the methods introduced in this study are somewhere in the middle of this evolving process. None of these methods are totally new and have certainly not reached maximum potential. This means that the results shown here could improve dramatically in the next few years. Accuracy will also improve as higher resolution imagery and digital elevation models become more readily available.

I have mentioned several times throughout this study that these methods can not completely replace a physical survey. While this is the case today, one must 'never say never' when technology is involved. There will likely be a time in the future where a developer never sets foot on a property until the day ground is broken for their new development.

REFERENCES

American Legal Publishing Corporation, 2005. *Austin, Texas Code of Ordinances.* Available online at http://www.amlegal.com/austin_tx/

Avent, John – Part Owner: Austin Blue Sky Investments. A property development firm located in Austin Texas. Personal Communication.

Capitol Area Planning Council, 2005. *Information Clearinghouse, Geospatial Data.* Available online at http://www.capco.state.tx.us/ Information_Clearinghouse/geospatial_main.asp

de Boer, Th. A. 1993. *Land Observations by Remote Sensing.* Langhorne, PA: Gordon and Breache Science Publishers.

Eyton, J. Ronald. 1990. "Color Stereoscopic Effect Cartography." Cartographica 27: 20-29.

Eyton, J. Ronald. 1991. "Rate-of-Change Maps." Cartography and Geographic Information Systems 18: 87-103.

Eyton, J. Ronald. (2004). *Terra Firma.* Unpublished software package for digital image processing and terrain analysis. San Marcos, Texas: Texas State University.

Harris, John – Part Owner: Austin Blue Sky Investments. A property development firm located in Austin Texas. Personal Communication.

Horne, Richard. (1999). *3Dem.* Software package for creating 3D terrain scenes and animations.

Klier, Cammi – Owner: Custom Design Services. A residential design and architecture firm located in Austin Texas. Personal Communication.

Klier, John D. and J. Ronald Eyton. 2004. "Logarithmic Enhancement of Color Stereoscopic Effect Cartography." In *The Papers of the Applied Geography Conferences Held in St. Louis, Missouri 20-24 October 2004,* edited by Burrell E. Montz and Graham A Tobin, 198-202.

Ludwig, Gail S. 1996. *Virtual Reality: A New World for Geographic Exploration.* [on -line]. University of Missouri – Columbia: available online at http://www.utexas.edu/depts/grg/eworks/wie/ludwig/earthwor.html: Internet: accessed 20 April 2005.

McMahan, C. A., R. G. Frye, and K. L. Brown. 1984. The Vegetation Types of Texas. Texas Parks and Wildlife, Austin, TX.

Microsoft. (2002). *Streets and Trips.* Comprehensive mapping software.

Texas Natural Resources Information System, 2005. *Digital Data Download.* Available online at http://www.tnris.state.tx.us/digital.htm.

U.S. Geological Survey, 1980. "The Quiet Revolution in Mapping." USGS Annual Report. 2-16.

Wilkie, David S., and John T. Finn. 1996. *Remote Sensing Imagery for Natural Resources Monitoring.* New York: Columbia University Press.

Woodwell, George. 1984. *The Role of Terrestrial Vegetation in the Global Carbon Cycle*. New York: John Wiley and Sons

Young, A. 1972. *Slopes* London: Longman Group LTD.

VITA

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