UTILITY OF THE AMERICAN VITICULTURAL AREAS OF TEXAS INFORMATION SYSTEMS (AVATXIS) AS A TOOL IN THE CHARACTERIZATION OF THE TEXAS WINE REGIONS

A Thesis

by

ELVIS ARREY TAKOW

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2008

Major Subject: Rangeland Ecology and Management

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	Douglas Loh
Committee Members,	Edward Hellman
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ABSTRACT

Utility of the American Viticultural Areas of Texas Information Systems (AVATXIS)
as a Tool in the Characterization of the Texas Wine Regions. (December 2008)

Elvis Arrey Takow, B.S., Texas A&M University

Co-Chairs of Advisory Committee: Dr. Douglas K. Loh
Dr. Robert N. Coulson

Geographic Information System (GIS) based computer applications are becoming increasingly popular for delivering, visualizing and analyzing spatial databases. Driven by advances in computing technologies, GIS applications are increasingly used by non-GIS experts as knowledge support tools that allow instant access and visualization of spatial data across the internet. The American Viticultural areas of Texas (AVATXIS) is an example of a web-based GIS tool that we have developed to help viticulturists better understand wine growing regions in Texas. The application allows users to spatially query and visualize a range of edaphic and climatic factors that influence vine growth and grape production. By providing growers a wide variety of climatic and edaphic data sets and an intuitive, easy to use interface for visualizing and downloading this data, AVATXIS serves as an effective tool for characterizing the Texas wine regions.

Research in the field of viticulture states that "Climate governs whether grapes will survive and ripen, what varieties do best where, and some of the characteristics of the resulting wines". For AVATXIS, a number of specific climate indices critical to wine production were identified through the current viticulture literature and by consulting with experts. These indices include monthly summaries of maximum, minimum and mean temperature, precipitation and Growing Degree-Days (GDD). Publicly available climate data was used to create novel GIS layers for each of these indices. Similarly the importance of soil type to vine growth is recognized, but its relationship to wine quality remains controversial. Publicly available soil data were used to create GIS layers representing simple soil indices (pH, soil texture, depth to bedrock, permeability, available water capacity, and bulk density) useful to the wine grower. These climate and soils data form the central database used by AVATXIS. The intuitive, user interface allows any combination of these GIS layers to be rapidly retrieved and visualized through a standard web-browser by any user of the AVATXIS system.

DEDICATION

This thesis is dedicated to my immediate family. I only wish you were all here with me to witness this. I would never have made it this far without the love and support you have showed me over the years. Even though you are miles away, I can constantly feel your presence. Dad, you have always been my inspiration to work hard and never give up on my dreams. You taught us the value of hard work as we watched you work on your Ph.D. Dad, you somehow manage to convince us that working towards a graduate degree and putting our education ahead of everything else is paramount in life. Mom, I am not sure where to begin. You have always told us to make you proud and I hope we are on the right track. Gus, you are the baby of the family and all I have ever tried to do is set an example for my little brother to follow. To the Downey family, I would be lost in life without your influence. Being so far away from my immediate family has always been tough but you have always made me feel at home. People often ask how I can go so long without seeing my family and I often say to myself that I see them every day. Thanks for all the love!

ACKNOWLEDGMENTS

Several individuals made the publication of this thesis possible. My immediate family and close friends deserve special recognition for the support and love they showed me in getting through this endeavor. My family instilled certain values in me about achieving personal goals and even though they may be a few thousand miles away, I can constantly feel their presence. They have always been there for me and continue to believe in my ability to succeed in life. I would like to acknowledge Douglas Loh for taking me on as a graduate student and giving me the initial opportunity to be in this unique position. His advice and guidance have played a crucial role in my life and I will be eternally grateful to him.

None of my work would be possible without Robert Coulson and the unique opportunity he afforded me by providing the environment to take on this research. Without his guidance and words of wisdom, I would be completely lost in the process. “Bob is indeed always right”! I would also like to acknowledge Maria Tchakerian who literally walked me through this research endeavor. Her expertise and guidance has been invaluable and my success is a direct result of her keeping me on track. None of my work would be possible without the guidance and funding from Ed Hellman. He has been an excellent inspiration and committee member who indeed made all of this possible. Andrew Birt and Hyunsook Kim are two of the best programmers and analytical minds I have ever come across. Andrew Birt deserves credit for helping me with programming questions throughout the project as well as data analysis. Finally I would like to acknowledge the Knowledge Engineering Lab (KEL) for providing me the environment to undertake this research. Everyone at KEL deserves special acknowledgement for the support and patience in dealing with me over the last 2 years.

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CHAPTER I

INTRODUCTION

Introduction

The ability to describe the character and conditions of a vineyard site through the quality of a finished wine should be one of the most sought out characteristics of a wine grower. This distinctive expression is often ultimately dependent on the quality of the site or the vineyard's "terroir".

Terroir is a holistic concept that encompasses vineyard location, soils, climate and topography as well as other environmental factors (Jones et al., 2004). Spatial references are important to many of the factors necessary to determine terroir. The spatial and temporal variables associated with grapevine growth and fruit production, are ideally suited to the application of spatial information systems (Smith 2002).

The American Viticultural Areas of Texas Information System (AVATXIS) was developed as a computer based application that integrates, analyzes, interprets, and displays information associated with the Texas wine regions to characterize the growing regions.

This thesis follows the style of Landscape Ecology.

Assessing a site's physical characteristics is arguably the single most important process that any potential grape grower will encounter when starting out (Jones and Hellman, 2003).

AVATXIS uses GIS technology to characterize the American Viticultural Areas of Texas (AVAs) based on physical characteristics of soil, climate and topography. AVATXIS provided access to spatially referenced soil factors of pH, soil depth, soil texture, available water capacity and bulk density. Spatial climatic data from the Daily Surface Weather and Climatological Summaries website (http://Daymet.org), Thornton, et al., 1997) was used to describe the Texas AVAs. This climatological summary was derived for the period of 1980-1997 and produced on a 1 kilometer grid over the entire conterminous United States.

Climate variables used in the characterization of the wine regions include precipitation, maximum temperature, minimum temperature, average temperature, vapor pressure, ripening period mean temperature, and growing degree days. According to Cox (1999), "Climate and soils have been recognized as the most important environmental factors for growing great wine grapes."

Objectives

The specific objectives of this thesis are as follows (i) characterize the Texas wine regions based on physical characteristics including soil, climate, and topography; (ii) develop a web-based GIS to deliver information associated with factors of soil, climate and topography; (iii) integrate, display, and analyze edaphic and climatic factors that affect the performance of vineyards; (iv) provide a spatial information tool that allows wine growers to better understand their growing regions and the edaphic and climatic factors that influence grapevine growth and fruit production; (v) provide access via the Internet to AVATXIS thus providing security for the database.

Approach

The approach of this thesis will be to first, provide a history of geographic information systems (GIS) and the Internet in Chapter I. The second chapter provides a background of wine in Texas and each of the 8 American Viticultural Areas of Texas, as well as a brief history of how an AVA gets established. This chapter also discusses the rationale for an Internet-based approach. The third chapter discusses how descriptive data/factors were selected based on literature reviews, and process of the acquisition and compilation of the data sets as well as the methodology of how AVATXIS was developed and configured using ArcIMS®. Chapter IV provides a detailed discussion and description of the soil and climate variables in relation to their significance for grapevine growth. This chapter also describes each individual Texas AVA based on the indices as characterized by AVATXIS. This chapter does not attempt to identify ideal regions for grape growth but rather simply describes the regions based on the factors. The fifth chapter provides an overview of AVATXIS as well as the rationale supporting this research. Chapter V outlines the significance of using a web-based system. A list of future work to be accomplished regarding AVATXIS and how this work may be influenced by changes in technology is provided in Chapter VI. The final chapter, Chapter VII, presents some conclusion to the aforementioned objectives.

Background of GIS and the Internet

The Internet is a global resource connecting millions of users. **G**eographic **I**nformation **S**ystems (GIS) evolved as the answer to a basic, but difficult question: "How can information existing in a specific place at a specific time be analyzed and manipulated?"

Until the advent of GIS, analog maps (typically presented as paper maps) served as the basic means of storing and displaying geographic data. The primary limitation of analog maps lay in the fact that only a small portion of the data could be manipulated at one time. This makes management a very time consuming process. As the use of digital storage for geographic data became more common, the manipulation and retrieval of the data became faster and easier to handle. The problem of relating different geographic features to each other, however, still remained. Geographic Information Systems have enhanced the efficiency and analytic power of traditional mapping.

A Geographic Information System provides the ability to analyze and model data in a spatial context. The ability of a GIS to manipulate data from specific geographic locations makes it possible to create a realistic perspective of the world and view the effects of future actions. Geographic data is dynamic and constantly changing with time. GIS, through the use of the Internet, has become a source of spatial data. Its unique accessibility, facilitated through the use of the Internet presents a greatly enhanced environment for the decision-making process. GIS technology is becoming an essential tool in the effort to make informed spatial decisions.

Geographic Information Systems have historically referred to the use of a single workstation type environment where one central computer housed all the necessary hardware and software. The limitations of these computing platforms often confined users to merely supporting the evolution of a single project or departmental GIS. Present day advances in technology have shown a drastic shift from single workstations to enterprise environments. These advances have been coupled with increased interoperability between geographic information systems and multiple users. Notable developments in computer technology such as improved speed, storage capacity, systems software, and relational database management systems, have been key in the popularization of GIS for decision making of web-based systems. According to Longley & Batty (2003), "there is recognition within the GIS community that the web provides a new medium for participation and its response has come in the form of software technologies that provide the capability to implement GIS in a distributed environment."

With the advent of internet technology, GIS is now openly accessible and can be effectively disseminated to more users. According to Brown and Kraak (2001), "early implementations of online GIS were mainly dissemination of static maps, interactive maps with pan-identity-zoom features, support for client/server designs, and advanced cartographic and geo-visualization tools." Internet Based GIS has now emerged to include web-based information GIS services with the potential to interact multiple systems/servers with several users hence supporting more advanced functions. This emergence has enabled the move away from stand-alone systems towards thin-client architecture with the potential for an unlimited number of users. A thin-client architecture network depends primarily on the central server for processing data and mainly focuses on conveying input and output between the user and the remote server. In other words, the thin-client architecture is a system where minimal work is performed by the user's computer thus relying on a central server that does the majority of the processing requested by the user.

Spatial queries can be run from remote systems by users, allowing the majority of the data processing to be done on a server that is usually much faster than typical workstations. The results of whatever queries the user requested may include spatial data, decision support, spatial modeling, and some form of GIS-based service. Software packages developed by ESRI (Arc/View GIS®, ARC/INFO®, and ArcIMS®) have been developed to allow GIS users the ability to distribute their spatial data, in vector format, through the Internet with minimal manipulation of their current GIS data.

This thesis provides an example of how to implement such an interactive GIS via the Internet to integrate, analyze, interpret, and display information associated with the Texas wine regions. Using ESRI's ArcMap and ArcIMS®, AVATXIS provides an example of how to apply web-based technology to overcome the shortcomings of previous Internet-based methods. AVATXIS allows users to make sense of large amounts of soil, climate and topographic data by allowing for both spatial and temporal analysis.

CHAPTER II

BACKGROUND

The Texas Wine Regions

The history of viticulture in Texas spans three centuries and precedes the introduction of wine grapes to California by almost a century. Franciscans, who in 1682 established a mission at Ysleta on the Rio Grande near El Paso, brought with them grapevines from Mexican missions. Subsequent travelers often called attention to the productive vineyards of the El Paso valley, which continued as a leading grape-growing and wine-producing area until the early twentieth century. Viticulture was almost totally foreign to the agricultural experience of most Anglo-American settlers in Texas during the 1800s. However, the influx of European immigrants from wine-producing countries brought a new interest in grape culture and wine-making. These immigrants planted quality vinifera vines from Europe, which in most cases soon failed. However, as the prohibition movement grew, attention turned more to table grapes and varieties suitable for making sterilized grape juice. The last wineries closed in 1919, when the state legislature voted Texas legally dry. In 1976 the Llano Estacado Winery was established near Lubbock. In 1985 there were fifteen wineries in Texas, and several new ones were being bonded each year. Wine production in Texas grew rapidly in the 1980s. In 1982 the state produced 50,000 gallons of wine. By 1993 it produced well over a million gallons a year and was the fifth-largest wine-producing state in the country (Templer, 2008).

Texas is home to eight American Viticultural Areas as defined by current regulations administered by the United States Department of the Treasury Alcohol and Tobacco Tax and Trade Bureau (TTB). The TTB oversees the creation and adjustment of the AVA system. Applicants must provide proof of geographic and climatic significance along with historical precedent for wine production, in addition to suggesting and mapping the boundaries of a proposed region. An American Viticultural Area is defined as “a delimited grape-growing region distinguished by geographical features, the boundaries of which have been delineated by an approved by map” (Code of Federal Regulations, 2001).

An AVA is not a grade of quality, it merely allows wine producers and consumers to differentiate and authenticate the growing regions. Debate continues among winemakers about precisely how useful AVAs are in helping consumers assess the quality of the wines they are buying.

How Does an AVA Get Established

An American Viticultural Area (AVA) is a designated wine grape-growing region in the United States. Figure 1 shows current locations of Texas AVAs. They are distinguishable by geographic features and boundaries defined by the TTB. AVAs are defined at the request of wine grape producers and other petitioners. Previous to the establishment of the AVA system in the 1960s wine appellations of origin in the United

States were chosen based on state or county boundaries. All of these appellations were grandfathered into federal law and may appear on wine labels as designated places of origin. Many of the past wine appellations are very distinct from the current AVAs.

Petitioners are required to provide certain information when applying for a new AVA, and are also required to use USGS (United States Geological Survey) maps to both describe and illustrate the boundaries. Current regulations impose some of the following conditions on future AVAs:

- Evidence that the name of the new AVA is locally or nationally known as referring to the proposed area.
- Historical and current evidence that the described boundaries are legitimate.
- Growing conditions such as climate, soil, elevation, and physical features should be distinctive.
- A narrative description of the boundaries based on features which can be found on United States Geological Survey (U.S.G.S.) maps of the largest applicable scale.

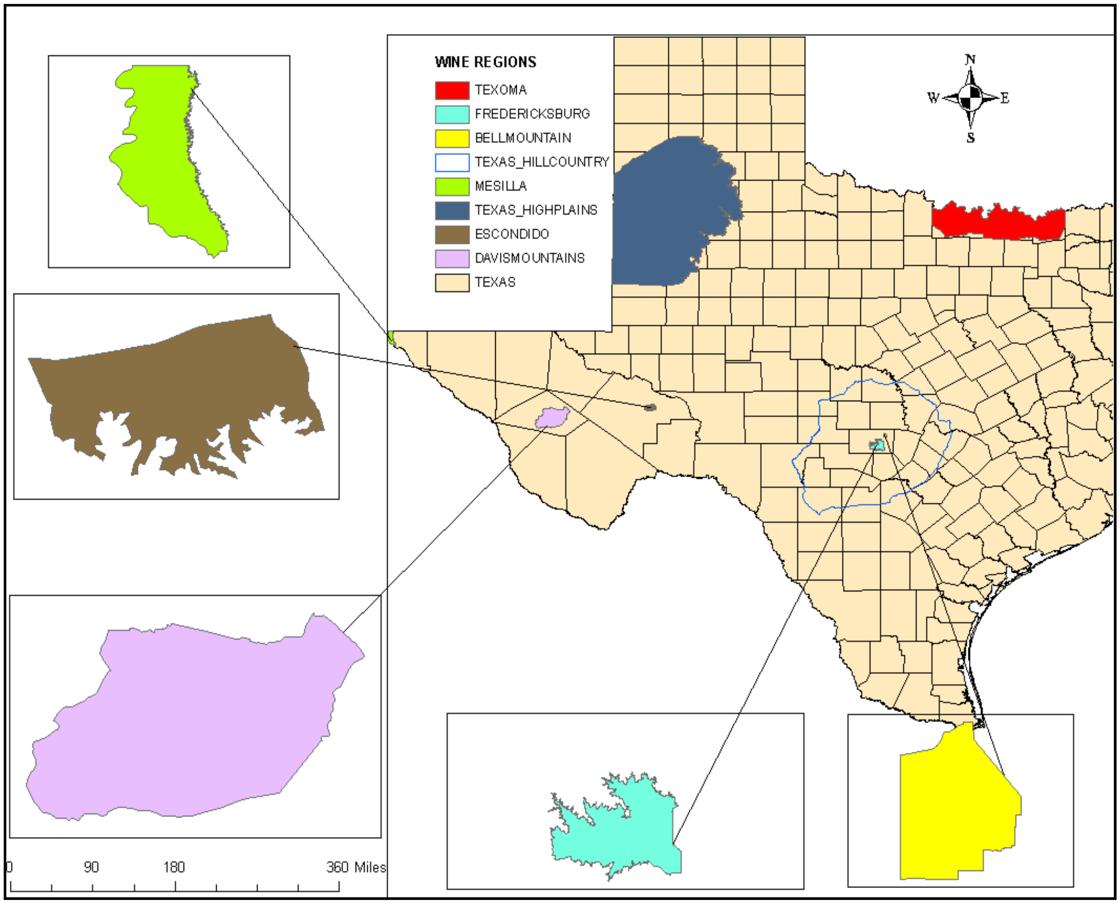

Figure 1 Texas American Viticultural Areas and their geographic location

AVAs should be based on features that influence growing conditions hence climate, soil, and topography. They may extend across political boundaries and there are no maximum or minimum requirements on the size of an AVA. Eighty-five percent of wine labeled as originating from a Viticultural Area must be made from grapes grown within the area's boundaries. The Lone Star state is now home to more than 150 wineries and eight federally approved Viticultural Areas. Texas ranks fifth in total wine production in the United States.

Current Texas AVAs

Bell Mountain

The Bell Mountain viticultural area is located in Gillespie County, Texas. This AVA is entirely contained within the Hill Country AVA and covers approximately 6300 acres on the south and southwestern slopes of Bell Mountain in northeast Gillespie County. Bell Mountain AVA was the first designated AVA in Texas, and was established in November 1986.

Texas Davis Mountains

The Texas Davis Mountains viticultural area is located in Jeff Davis County, in the Trans-Pecos region of West Texas. Sitting just southwest of the Escondido viticultural area, this AVA was the last in Texas to be recognized in the 20th century. This viticultural area is at the highest elevation of all Texas AVAs and is surrounded by the Chihuahua desert. The land within the boundaries of the AVA ranges between 4,500 feet (1,372 m) and 8,300 feet (2,530 m) above sea level. It was established in May of 1998.

Escondido Valley

The Escondido Valley viticultural area is located in Pecos County, Texas. This AVA covers approximately 32,000 acres along Interstate Highway 10 and was established in June of 1992. It was the fifth designated wine area in the state of Texas.

Fredericksburg in the Hill Country

The Fredericksburg in the Texas Hill Country viticultural area is located entirely in Gillespie County, Texas, in the central part of the State approximately 80 miles west of Austin. It surrounds the town of Fredericksburg, which was settled by German immigrants in the nineteenth century. These settlers were the first to cultivate grapevines in the Texas Hill Country. This AVA covers approximately 110 square miles and was established in January 1989. The AVA is over 200 miles (322 km) from the Gulf of Mexico, and feels little effect of the hot, humid, coastal winds.

Texas High Plains

The Texas High Plains viticultural area is located in Armstrong, Bailey, Borden, Briscoe, Castro, Cochran, Crosby, Dawson, Deaf Smith, Dickens, Floyd, Gaines, Garza, Hale, Hockley, Lamb, Lubbock, Lynn, Motley, Parmer, Randall, Swisher, Terry and Yoakum counties, Texas. This AVA covers most of the south plains and was approved in April 1993. This is the second largest American Viticultural Area in Texas, and covers an area of over 8,000,000 acres (32,375 km^2).

Texas Hill Country

The Texas Hill Country viticultural area is located in portions of McCulloch, San Saba, Lampasas, Burnet, Travis, Williamson, Llano, Mason, Menard, Kimble, Gillespie, Blanco, Hays, Kendall, Kerr, Edwards, Real, Bandera, Bexar, Comal, Guadalupe, Medina, and Uvalde counties, in the State of Texas. This AVA was established in December of 1991, covers approximately 9,000,000 acres (36,422 km^2), and is the second largest AVA in the United States. It is located north of San Antonio and west of Austin,

Mesilla Valley

This AVA was established in March of 1985 and contains portions of New Mexico as well as Texas. The Texas portion of the Mesilla Valley viticultural area is located north and west of El Paso within El Paso County, Texas. The largest portion of the AVA is located in Dona Ana County, New Mexico. Spanish explorer Don Juan de Oñate arrived in the area in 1598 and named a Native American village in the valley Trenquel de la Mesilla, from which the valley as a whole became known as Mesilla Valley. Although viticulture began in nearby El Paso as early as 1650, grapes were first planted in the Mesilla Valley only in the early twentieth century, near the town of Doña Ana.

Texoma

Texoma is located in north central Texas south of Lake Texoma and the Red River that borders the states of Oklahoma and Texas. This AVA was established in January of 2006, covers approximately 3650 square miles, and includes Montague, Cooke, Grayson, and Fannin counties. The Texoma region is where 19th century viticulturist Thomas Volney Munson discovered that grafting *Vitis vinifera* grapevines onto Native American varieties of vine rootstock resulted in vines that were resistant to the insect pest phylloxera.

Rationale for an Internet-Based Approach to AVATXIS

The Internet and the advent of the computing age provided the technical frame work on which GIS is built. As GIS use expands beyond the current core of the GIS community, the need to disseminate GIS capabilities has grown. The spatial and temporal implications of AVATXIS enable instant access by the user to data which allows wine growers to better understand their growing regions, along with the edaphic and climatic factors that influence grapevine growth and fruit production. This instant access enhances the potential wine grower's ability to adjust management practices based on local spatial information.

An Internet- based approach to AVATXIS enables wine growers to evaluate opinions about climate and soil factors of the various wine regions by using annotated base maps representative of these factors. These created maps provide the basis for structured characterization of the Texas wine regions based on physical characteristics such as soil, climate, and topography. The vast geographic extent of the state of Texas coupled with the comparison of geographically dispersed wine regions warrants the use of a spatial information system. These comparisons and characterizations can now be carried out through spatial data analysis, processing and modeling made possible with AVATXIS

CHAPTER III

METHODOLOGY

How AVATXIS Was Developed

As is the case with most web-based applications, one of the preliminary development steps involves the configuration of the server. The ArcIMS spatial server is the key to ArcIMS and hence the key to the success of AVATXIS. It processes requests for maps and all related information to the Texas wine regions. For AVATXIS, windows server 2000 was used as the operating system while ArcIMS was used as the server software. This software was chosen because of the ability to serve map graphics for simple display as well as the ability to stream live GIS data via the internet for more advanced display and analysis. AVATXIS was configured as 8 separate map services each representing the various Texas viticultural areas. Each map service is configured identically with data layers representative of the climate, soil, and topographic factors of the region.

AVATXIS called for the formation of 8 individual ArcMap documents (MXD) for each of the 8 Texas wine regions. Each MXD comprises separate geographic data layers of the region that representative of each of the soil, climate, and topography factors necessary for characterization of the AVA in question. Figure 2 displays the table of contents of the High Plains MXD. Every MXD created has an identical structure but representative of data corresponding to the respective viticultural area.

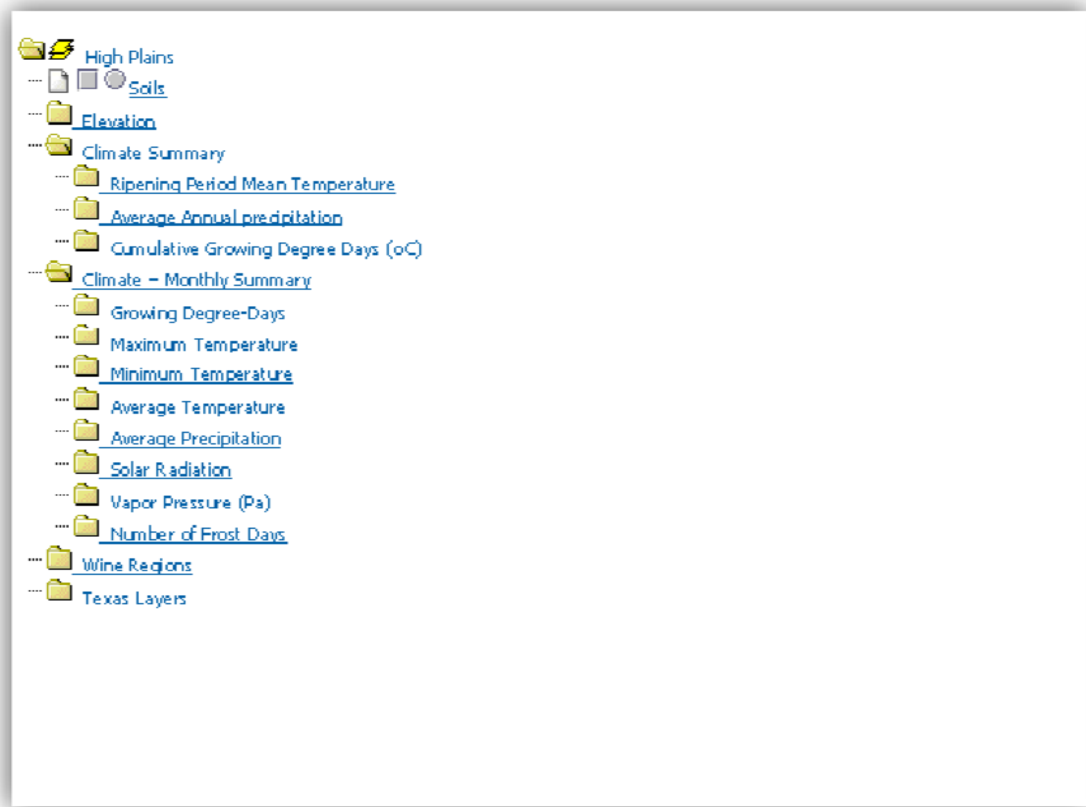

Figure 2 Structure of geographic data layers for each AVA MXD

Determination of Factors for Characterization of Wine Regions

Literature was reviewed to determine environmental factors for viticulture that would be important to incorporate in AVATXIS for accurate characterization of the Texas wine regions. The central theme of this thesis advocates the significance of soil, climate and topography of the environment in characterizing the Texas wine regions. Through analysis of these physical factors, this research will contribute to a more complete understanding of the wine regions.

Research on the viticultural environment, wine grape growing, and vineyard site selection was reviewed using journal articles, books, Internet resources, and personal communication with viticulture experts. Dialogue with viticultural specialist was crucial in making final decisions on the factors to consider in the characterization of the wine regions.

Data Acquisition and Compilation

Soil Variables

The development of AVATXIS began at the state level with the collection of soil, climate, and topographic data. The first step involved the analysis of the soil factors for the various wine regions. This process began with the construction of a comprehensive database of the soil properties based on the STATSGO alphanumeric map unit ID (such as TX001 - Texas mapunit 001). All soil properties data was downloaded and prepared by the Soil Information for Environmental Modeling and Ecosystem Management (http://www.soilinfo.psu.edu) website.

STATSGO consists of georeferenced map data and associated tables of attribute data. It is a general soil association map developed by the National Cooperative Soil Survey (NCSS). This data base consists of a broad based inventory of soils and nonsoil areas that occur in a repeatable pattern on the landscape and that can be cartographically shown at the scale mapped. Map units in STATSGO are a combination of associated phases of soil series. A soil series is the lowest level in the U.S. system of taxonomy and the most homogeneous with regard to properties. A phase of a soil series is based on attributes and factors that affect soil management. STATSGO, as delivered by the Natural Resource Conservation Service (NRCS), poses substantial problems for modelers not familiar with soils data or geographic information systems.

Soils are classified to provide scientists with generalized information about the nature of a soil found in a particular location. Areas that share comparable soil forming factors produce similar types of soils hence making classification possible. Soils are classified by name or associations using STATSGO alphanumeric map unit ID as the common link between soil map units and the corresponding soil map unit name. The dominant soils making up the landscape are depicted by delineations. The soil map unit data set consist of closed polygons that are generally geographic mixtures of groups of soils and non-soil areas. The map unit ID uniquely identifies each closed delineation map unit. Each map unit ID is linked to a map unit name also called an association. The map unit ID is also the key for linking information in the Map Unit record tables. This attribute data base gives the proportionate extent of the component soils and the properties for each soil which include soil texture, depth, available water capacity, soil pH, permeability, and bulk density. Table 1 shows a brief description of each soil property, the relevant unit of measure, how it is measured, and its significance to vine growth.

Soil Texture

The properties for each soil are further calculated for 11 standard soil depths up to 250cm. This is due to the fact that the number, thickness, and depth to top and bottom of soil layers in the STATSGO data varies widely from one soil component to another, even within the same map unit.

Table 1 Description of soil properties of Texas AVAs

Classification	**Unit**	**How It Is Measured**	**Significance To Vine Growth**
Soil pH	Concentration $[H^+]$; does not carry units	Obtained data for 11 standard layers from STATSGO composition and layer tables by computing mean value for each component.	Gives an indication of fertility and nutrient balance (ideal range is 5.5-8.0).
Permeability	cm/hr	Obtained data for 11 standard layers from STATSGO composition and layer tables.	Permits deep root growth as well as a steady and moderate supply of water (>5cm/hr).
Bulk Density	g/cm3	Obtained data for 11 standard layers from STATSGO composition and layer tables.	Measure of soil compactness; affects soil porous space consequently internal drainage.

Table 1 Continued

Classification	**Unit**	**How It Is Measured**	**Significance To Vine Growth**
Texture	Categorical	Obtained data for 11 standard layers from STATSGO composition and layer tables.	An indirect measure of the internal drainage and water holding capacity of the soils.
Depth	cm	Obtained data from STATSGO composition and layer tables of MU_ROCKDEPM.	Gives an indication of how well vines can deal with dry periods (range 75-100cm).
Available Water Capacity	cm	Obtained data from STATSGO composition and layer tables of MU_AWC.	Adequate values allow vines to deal with periods of moderate drought.

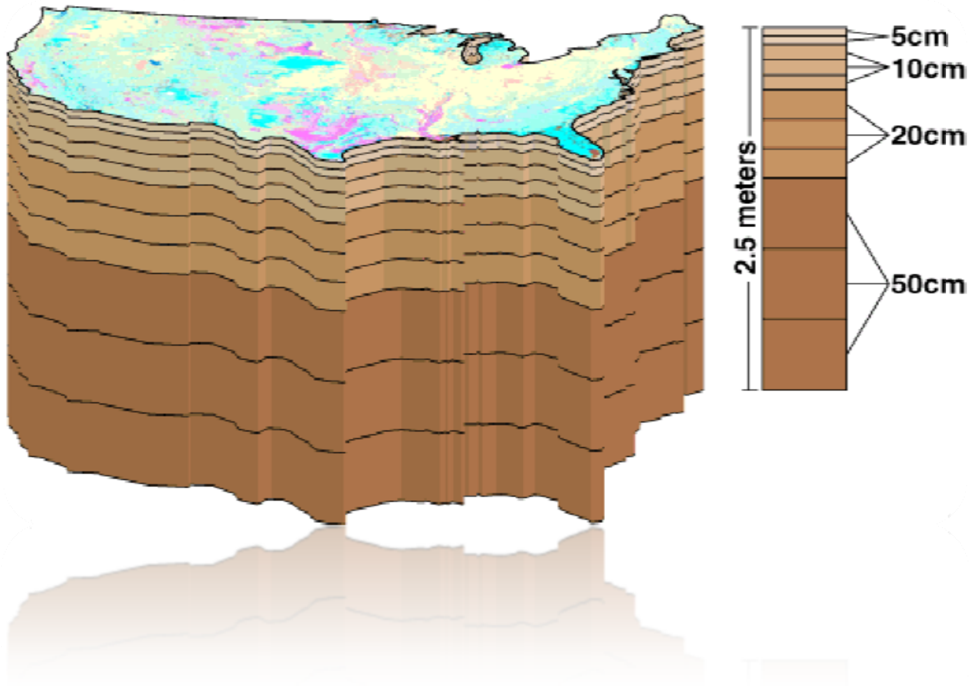

Figure 3 Structure of 11 standard STATSGO layers for entire U.S.

Table 2 provides an illustration of the different soil textures within the STATSGO component and layer tables. These texture types describe the soils at various levels of depth representing the 11 standard layers. Table 3 shows the Callisburg-Gasil-Aubrey (mapunit TX084) association in the Texoma AVA with the various soil texture types at the 11 standard depths. Figure 3 illustrates the 11 standard STATSGO layers for the entire U.S.

Table 2 Different soil textures within the STATSGO component and layer tables

Soil Texture Class	Class Abbreviation
Sand	S
Loamy sand	LS
Sandy Loam	SL
Silt Loam	SiL
Silt	Si
Loam	L
Sandy Clay Loam	SCL
Silty Clay Loam	SiCL
Clay Loam	CL
Sandy Clay	SC
Silty Clay	SiC
Clay	C
Organic Materials	OM
Water	W
Bedrock	BR
Other	O

Table 3 Example of soil texture types at 11 standard depths for CALLISBURG-GASIL-AUBREY map unit

Depth	Soil Texture Class
0-5cm	Sandy Loam
5-10cm	Sandy Loam
10-20cm	Sandy Clay
20-30cm	Clay
30-40cm	Clay
40-60cm	Clay
60-80cm	Sandy Clay
80-100cm	Sandy Clay
100-150cm	Sandy Clay
150-200cm	Bedrock
200-250cm	Bedrock

Depth

The location of bedrock with respect to the land surface is often needed in surface and subsurface environmental modeling applications. The STATSGO database contains information on the range of depth-to-bedrock for each map unit component.

The depth to bedrock for each map unit is given by the Info table MU_ROCKDEPM, which was related to the map units using "MUID" as the relate item.

Available Water Capacity

This is defined in the NRCS Soil Survey Manual as "The volume of water that should be available to plants if the soil, inclusive of rock fragments, were at field capacity". The available water capacity for each map unit is given by the info table MU_AWC, which may be related to the map unit coverage using "MUID" as the relate item. The available water capacity for each STATSGO map unit was computed at three depths, 100, 150, and 250 cm, measured from the surface. These depths were chosen for the following reasons:

- Many models use a root-zone depth of 100 cm
- Bedrock information is only reliable to a depth of about 150 cm
- 250 cm is the maximum depth for which data were available for any map units.

Soil pH

Soil pH is a measure of the acidity or alkalinity of the soil. The pH results from the interaction of soil minerals, ions in solution, and cation exchange. The mean pH was determined for each of 11 standard layers for each map unit using data from the STATSGO Comp and Layer tables. The standard layers were introduced because of the wide variation in the number, thickness, and depth to top and bottom of soil layers in the STATSGO data from one soil component to another, even within the same map unit. Variable layers cause problems for many environmental models and GIS operations.

Bulk Density

Bulk density (g/cm^3) is the ratio of the mass of soil to its total volume (solids and pores together). Bulk density (BD) as recorded in STATSGO is a total, or wet, bulk density which is a measure of the total mass of a moist soil per unit volume. The following steps were involved in computing the BD for the 11 standard layers:

- Computing the mean bulk density for each component layer.
- For each component, determining the contribution of each component layer to the 11 standard layers.
- For each map unit, combining the contributions of all components to compute the bulk density for each layer.

If the component was identified as "WATER", it was excluded from the computation of BD.

Permeability

Soil permeability is a measure of the ease with which air and water move through the soil. The permeability rate (cm/hr) was determined for each of 11 standard layers for each map unit of each state using data from the STATSGO Comp and Layer tables.

Climate Variables

The next step involved the analysis of the climate data. Climate is defined as weather conditions over a long period of time, usually 30 years or more. The climate variables critical to wine grape growing and necessary in the description of the Texas wine regions include daily maximum temperature (TMAX), daily minimum temperature (TMIN), daily average temperature (TAVG), annual precipitation (PPT), growing degree-days (GDD), ripening period mean temperature (RPMT), and solar radiation (Rs).

These variables were obtained from Daymet, which is a model that generates daily surfaces of temperature, precipitation, humidity, and radiation over large regions of the entire United States. These variables are produced using digital elevation models and daily observations and an 18 year daily data set (1980 - 1997). This daily data set of temperature, precipitation, humidity and radiation has been produced as a continuous surface at a 1 km resolution (Miller and White, 1998).

GDD on the other hand is determined by subtracting 50 ^{o}F (10 ^{o}C) from the mean daily temperature and calculating the cumulative sum through the growing season (April 1st through October 31st). This calculation of GDD is done programmatically using ESRI's ArcMap to establishing GDD surface data of the same resolution as the other climate data sets. All climate data is then incorporated into ArcMap, thus creating an MXD representative of each of the 8 Texas wine regions. The quantitative summary of climate variables is carried out by clipping grids of each data set to each of the 8 wine regions. This data can now be queried in order to accurately describe the Texas wine regions.

Table 4 lists the various climate variables, the unit of measure, how it was measured and the significance to vine growth.

Table 4 Climate variables used in description of AVAs

Classification	**Unit**	**How It Is Measured**	**Significance To Vine Growth**
Daily maximum Temp (TMAX)	°C/°F	AVG of high temp over a month or annually in 24 hour period.	Excessive heat (Temp) reduces photosynthesis and influences fruit flavors and color development.
Daily minimum Temp (TMIN)	°C/°F	AVG of low temp over a month or annually in 24 hour period.	Affects adapatability of grape varieties to a region.
Daily Average Temp (TAVG)	°C/°F	AVG of (TMAX +TMIN/2) over a month or annually in 24 hour period	Enables evaluation of risk of frost (range between AVG mean and AVG minimum temp), SFI for spring months.
Precipitation (PPT)	cm	Total accumulated PPT over month or annual period	Adequate PPT is needed for vine growth and fruit production.
Growing Degree-Days (GDD)	°C/°F	GDD is determined by subtracting 50°F (10°C) from the mean daily temperature. The physiological min of 50°F (10°C)	Cumulative amount of functional heat experienced by grapevines during a growing season defined as April 1 through October 31.

Table 4 Continued

Classification	**Unit**	**How It Is Measured**	**Significance To Vine Growth**
Ripening Period Mean Temp (RPMT)	°C/°F	AVG mean temp during the final ripening months which are July through September and the range is 15-21°C.	Period during growing season where rates of acid loss & sugar accumulation determine the potential style and balance of wine
Solar Radiation (Rs)	Joules	AVG over either a month or annual period of total daily amount of sun light (radiation).	Ample sunshine promotes fruit set and fruitfulness of new buds being formed in late spring. Leads to high production yields.

Topographic Variables

The final phase of data analysis involved the topography data. This process included the acquisition of elevation from the U.S. Geological Survey website (www.seamless.usgs.gov). Topographic categorization of the wine landscapes was carried out using several 10 meter digital elevation models (DEM) in order to determine areas of higher elevation, as well as calculate hill shade values.

This elevation data was obtained from the National Elevation Dataset (NED) which is a seamless mosaic of the best elevation data available. Due to the large size of the data sets, it was obtained in sections representative of the 8 wine regions. This data was further mosaic then clipped to the distinct boundaries of the Texas AVAs. The final 7.5-minute elevation data sets of each AVA were analyzed using ESRI's ArcMap and the spatial analyst function in order to determine hill shade values. Hill shade can greatly enhance the visualization of a surface for analysis or graphical display, especially when using transparency. Table 5 shows a summary of topographic variables considered in describing the Texas wine regions, how it was measured and the significance to grape vine growth.

Table 5 Summary of topographic factors relevant to grape vine growth as it is used in AVATXIS

Classification	**Unit**	**How It Is Measured**	**Significance To Vine Growth**
Elevation	meters	Obtained 10m resolution DEM grids from National Elevation Data set (NED).	Profound influence on minimum and maximum temperatures thus tremendous effects on air temperature.

How to Configure ArcIMS®

Figure 4 illustrates the interaction between the ArcIMS Spatial Server and configuration files, services, requests, and responses. It also outlines a brief illustration of the general ArcIMS architecture.

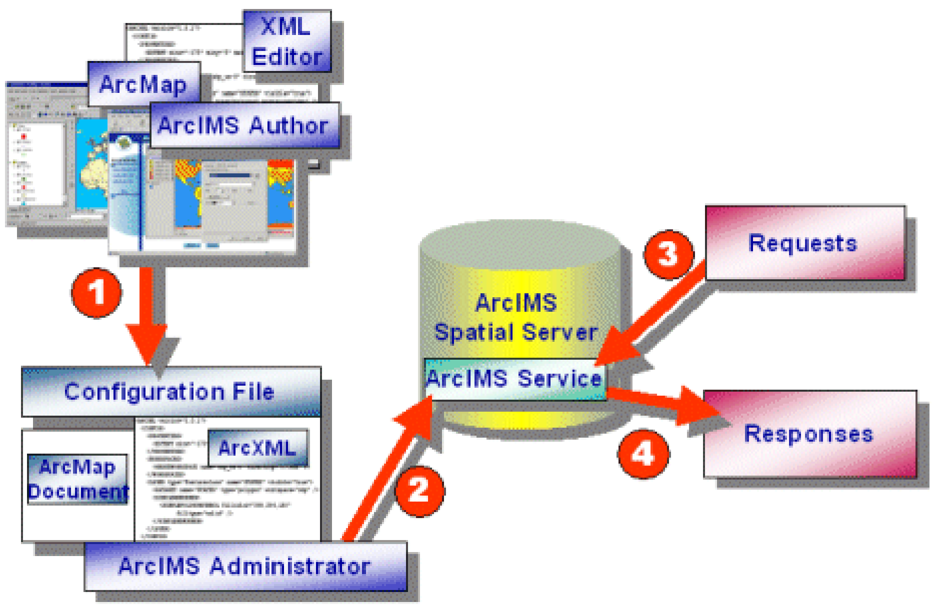

Figure 4 Schematic illustrating the system architecture for AVATXIS (Taken from www.edndoc.esri.com/arcims/9.0/elements/introduction.htm)

The following processes take place in communicating with the ArcIMS spatial server:

- Creation of a configuration file. In the case of AVATXIS, we create an ArcMap document for each of the 8 Texas AVA's. These are treated the same as map configuration files by ArcIMS.
- ArcIMS Administrator is used to start the ArcIMS Services on the ArcIMS Spatial Server with the configuration file, as the input. AVATXIS consist of several services as each of the 8 Texas wine regions was created as separate service.
- ArcIMS Spatial Server receives a request in ArcXML (the protocol for communicating with the ArcIMS Spatial Server). Requests are generated by a client such as the ArcIMS HTML Viewer and the requests vary from "Get Image, Get Feature, Get Layout, Get Extract etc.

When the ArcIMS Spatial Server processes a request, the results are returned in a response. ArcIMS Spatial Server generates a response in ArcXML. The ArcXML response generated by the ArcIMS Spatial Server is sent back to the Servlet Connector (the servlet connector extracts the ArcXML and sends the request on to the Application Server) through the Application Server. The Servlet Connector or JavaServer Pages (JSP) generates a new HTML page that is sent back to the PostFrame in the HTML Viewer. The JavaServer Pages (JSP) is used with the Java Connector to generate dynamic Web pages. A JavaServer Page is a text file, generally with a *.jsp extension, used in place of an HTML page. This new page replaces the previous HTML page and contains the ArcXML response. The ArcXML response is assigned to a variable XMLResponse in the page. It should be noted that the ArcXML response produced is dependent on the request thus may be the generation of a map or retrieval of data resulting in the generation of a map.

CHAPTER IV

DESCRIPTION OF TEXAS AVA'S

Prelude

Successful wine grape production is grounded upon a thorough understanding of the vineyard's site characteristics (Hellman and Kamas, 2002). The factors that influence this success include ideal climate along with optimum site characteristics of topography and soil. This section discusses the relevance of the different soil, climate and topographic factors to grape vine growth and fruit production. It further describes the different AVAs based on the aforementioned factors as they specifically occur in the different Texas viticultural areas.

Soil Variables

Soils are the most commonly described components of terroir (Wilson, 1998). The importance of soil type to vine growth is well recognized but its relationship to wine quality remains controversial (Gladstones, 1992). Many modern scientific writers have minimized the direct influence of soil type on wine quality as grapes are adapted to a wide variety of soil conditions but soil has a strong influence on grapevine growth and development. Variables that provide a means to describe soils in terms of attributes meaningful to viticulture are essential in characterizing the Texas AVAs.

Grapevines will tolerate a wide range of soils; however some writers claim that each soil imparts its own unique taste and mouth-feel to a given variety (Wilson, 1998). Soil properties affect the root system of the grapevine: roots absorb and conduct most of the vine's water and nutrient requirements to the aerial parts of the plant (Lanyon et al, 2004). Site characterization, of soils in the Texas AVAs involved analyzing factors of pH, soil depth, soil texture, available water capacity, permeability, and bulk density.

It is important to stress that the STATSGO map unit components are soil series phases (associations), and their percent composition represents the estimated proportion of each within STATSGO map unit. The composition for a map unit is generalized to represent the statewide extent of that map unit and not the extent of any single map unit delineation. These specifications provide a nationally consistent representation of STATSGO attribute soil data. A soil association is merely an ID or name that facilitates the process of uniquely classifying each soil but has no true value to the classification system. The worth of the system lies in the ability to collect, collate and present different soil information in a standard format useful to grapevine growth.

Soil pH

Grapevines do not perform well when soil pH is lower than about 5 due to stunted shoot and root growth (Conradie, 1983). According to Lanyon et al (2004), “at these low pH values the increased concentration of exchangeable aluminum is mostly responsible for the distorted root growth”. In soils with pH above 8.0, availability of nitrogen, calcium, magnesium, iron, manganese, copper and zinc are reduced. These high soil pH values are also associated with Boron toxicity (Saayman and Huyssteen,1981 ,Davidson 1991). Soils with pH above 8.3 are associated with elevated concentration of very fine carbonates that may cause severe lime-induced iron deficiency (Lanyon et al, 2004). The most common cause of lime-induced iron deficiency with high bicarbonate concentrations and associated high pH is either reduction in ferric iron concentrations or slower uptake by vines (Gelat, 1996).According to Lanyon et al (2004), “It is generally accepted that soil pH should be between 5.5 and 8.0 for optimum vine survival and growth”.

Depth

Deep soils allow the development of an extensive root system, buffering the plant against fluctuations in rainfall and potential drought thus allowing for a more consistent grape quality from year to year (Taylor, 2004). The ability of a soil to maintain moisture is crucial for good grape production especially in the absence of irrigation (Gladstones, 1992). Adequate depth for successful grapevine growth ranges from 75cm to 100cm.

According to Wolf and Boyer (2003), "A deep soil (>90cm) offers greater volume of potential soil moisture than does a shallow soil (<30cm).

Texture

Texture is the primary soil property that determines a soil's moisture holding capacity (Taylor, 2004). According to Gladstones (1992) "There are a wide range of soil texture types capable of fulfilling the moisture requirements of grapevines. They include gravelly alluvials, limestone -based soils and clays due to high water-holding capacity." Sands are not particularly suited to vine growth (due to poor moisture retention) unless large amounts of rainfall and ample irrigation is available (Taylor, 2004). The direct effects of soil texture on wine quality are poorly defined, but indirect effects of texture on soil hydrology are more important. Texture affects water-holding capacity of the soils and internal water drainage hence ideal vineyards would have loam, sandy loam, or sand clay loam textures (Kurtural, 2005).

Available Water Capacity (AWC)

The effect of Available water capacity (AWC) on vine performance is dependent on soil physical properties and concepts related to measurement and management of AWC in vineyards is well known (McCarthy et al, 1987). AWC affects yield, as well as fruit quality both directly and indirectly. The major effects are indirect and act via vegetative growth due to direct effects of leaf water potential, turgor, translocation or organic and inorganic substances and canopy photosynthesis (Lanyon et al, 2004).

According to Bravdo and Hepner (1986), “the rate of vegetative growth during each physiological stage of development affects fundamental processes of bud fertility, fruit set, berry and cluster size and accumulation and break down of sugars”. The indirect effects of AWC dominate in the oversupply of water while the direct effects dominate in the undersupply of water (Lanyon et al, 2004). Cass et al. (2002) postulated that optimal soil conditions for the best quality fruit was achieved when the AWC was approximately 15cm (150mm) based on a classification of soils devised by Hall et al (1977).

Permeability

Soil permeability is the ease with which air and water move through the soil. A quantitative measurement is made by observing the rate at which a column of water permeates the soil under saturated conditions. A consistent and moderate supply of water, along with deep and spreading root growth are some of the benefits of good drainage or permeability. Unimpeded soil drainage is often associated with the highest quality wine (Seguin 1986; Champagnol 1984). The internal water drainage and hence permeability of vineyard soils is the most important soil physical property and the desirable value is >5cm/hr (Kurtural, 2005).

Bulk Density

Generally, lower bulk density values have implied more pore spaces and better internal drainage of soils which consequently allows more rapid root development. This is a measure of the compactness of the soil which naturally interferes with internal drainage and could restrict root growth. According to van Huyssteen (1988),"bulk density values of about 1.6g/cm^3 or more are restrictive to root growth of most plant species, including grape". Suitable values for bulk density would be <1.5g/cm^3 (Wolf and Boyer, 2003). Bulk density of soil in raised beds (1.25 Mg m^{-3}) was significantly lower than in flat beds (1.5 Mg m^{-3}), which allowed more rapid root development and significantly higher root lengths in raised beds (Eastham et al, 1995).

Topography

The Topographic factors of a site are identified as having an effect on the vine production by influencing the mesoclimate of the site (Gladstones, 1992).Topography controls sun aspect and solar influx thus it plays an important role in grapevine growth and quality. Topographic factors such as elevation wield great influence on a site's climate. Particularly in hilly and mountainous terrain, elevation has a tremendous influence on maximum and minimum temperatures. Frost and freezing temperatures can drastically reduce vineyard profitability (Wolf and Boyer, 2003). At higher latitudes the angle of the slope becomes more important since radiation interception becomes more limiting. Steeper slopes will receive more radiation per square meter, given suitable aspect (Taylor, 2004). Gladstones (1976) contends that premium vineyards tend to have reduced diurnal fluctuation in temperature due to two or more of the following topographic characteristics:

- Tend to be close to large lakes or rivers if located inland
- Directly face the sun part of the day
- Slopes are on projecting or isolated hills and have outstanding drainage
- Located on slopes with excellent air drainage and situated above fog level

Vineyards are thus influenced by topographic features such as presence of water bodies and the existence of slopes.

Climate Variables

According to Gladstones (2001), "Climate governs whether grapes will survive and ripen, what varieties do best where, and some of the characteristics of the resulting wines". Climate variables can yield predictive indices that will help characterize the Texas wine regions. Climate exerts the most profound effect on the ability of a region or site to produce quality grapes (Jones et al., 2004). With the exception of low rainfall, which may be offset by intense irrigation, most climatic variables are impossible or cost prohibitive to control (Taylor 2004).Climate can be considered at 3 different scales in any discussion about viticultural areas: the macroclimate, the mesoclimate, and the microclimate.

Macroclimate refers to the prevailing climate or broad weather patterns of a relatively large area or geographic region. The mesoclimate is a more localized and specific climate, often influenced by topography. The effects of the mesoclimate are often on a scale of horizontal distances of as little as 500 feet (Wolf and Boyer, 2003). The microclimate of a vineyard describes the specific environment from the soil into the vine canopy. There can be tremendous differences between the microclimate within the vine canopy and the ambient conditions. These differences are often attributed to air temperature, sunlight, humidity, and management practices that influence these factors.

Temperature

Temperature is most significant in the months prior to ripening and plays a large role in the style of the wine production. The great wine regions tend to be characterized by low diurnal fluctuations in temperature around harvest (Gladstones, 1992). In general, minimal variations in temperature around the mean imply greater grape flavor, aroma and pigmentation at given maturity levels (Taylor 2004). According to Jackson and Lombard (1993), "provided the climate is warm enough to allow grape maturity, the quality is generally inversely related to the warmth and length of summer". Taylor (2004) reports that extremely high temperatures (>33°C or 91.4°F) results in reduced sugar assimilation by impeding transpiration and photosynthesis. According to Kliewer (1970), "approximately 90-100% assimilation is attained between 18-33°C (61.4-91.4°F)". Growing season temperatures plays a critical role in description of a viticultural area due to the influence on grape ripening and fruit quality (Hellman and Kamas, 2004). Vine growth is optimized by average temperatures of 73.4-77°F (Buttrose, 1969). Gladstones (1992) contends that fruitfulness tends to be improved by high temperature during early bud development in late spring.

Bud break is primarily influenced by air temperature- the warmer the air temperature, the earlier the bud break (Wolf and Boyer, 2003). The warm weather becomes a problem if it is interspersed with sub-freezing temperatures, hence large fluctuations in temperature over short periods of time. This leads to a risk of frost hazard which can be damaging to grapevine.

No one climate is necessarily ideal for grapevine growth as many aspects of the environment will ultimately play critical roles in the overall climate. Ideal climate entails a critical balance of a number of factors significant to successful fruit production and grapevine growth.

Precipitation

The adequacy of total or complete season rainfall for grapevine growth is an obvious climatic criterion (Gladstones, 1992). Lack of adequate rainfall can be of severe influence on grape productivity in the absence of good quality water for irrigation (Taylor, 2004). Johnson and Robinson (2001) suggest a minimum level of rainfall or irrigation of 50cm, but higher if the growing season is characterized by high evapotranspiration rates. According to Jackson and Schuster (1987),"Too much rainfall can be a problem and most quality wines are produced in regions where the annual rainfall does not exceed 70-80cm". Moisture availability at particular growth stages has important implications, thus it is the timing of the excess rainfall that is of greater consequence than the amount of the rainfall.

According to Gladstones (1992), flowering and bud set are both sensitive to moisture stress with marked effects on potential yield. During differentiation of fruitful buds in late spring /early summer (growing season), the vine is somewhat susceptible to excess moisture. Heavy rain at this time can produce vigorous growth which suppresses bud differentiation and fruit setting (Johnson and Robinson, 2001). Adequate rainfall from the harvest to natural leaf fall, is significant towards maintaining root growth, photosynthetic activity, and assimilates for the next vintage. According to Gladstones (1992), vigorous even budburst and early growth for the following spring are somewhat ensured by a good build up of assimilate post harvest.

Growing Degree Days

Growing season temperature is another critical aspect of climate for successful grapevine growth as it plays a crucial role in grape ripening and fruit quality. Growing degree days (GDD) is a measure of growing season temperature and can be used to compare an area's climate with that of a known winegrowing region. Degree-days are a rough measure of the cumulative amount of functional heat experienced by grapevines during a growing season defined as April 1^{st} through October 31^{st}. GDD is determined by subtracting 50 ^{o}F (10 ^{o}C) from the mean daily temperature and calculating the cumulative sum through the growing season. This base of 50 ^{o}F is used in calculations because virtually no shoot growth occurs below this temperature.

Cumulative Growing Degrees days is the summation of the individual GDD values for each month in the growing season (April 01^{st} to October 31^{st}). It is important to emphasize that grapes in all regions of Texas ripen well before the standard GDD cutoff date of October 31^{st} (end of the growing season) but this notion of cumulative GDD is useful comparing a region to known grape growing areas.

Ripening Period Mean Temperature

Comparisons among the world's wine producing areas show a broad association between average mean temperature during the final ripening month and the styles of wine produced. High acid levels result from grapes with ripening-month average means below 15°C thus the range for ripening period mean temperatures is 15-21°C (Gladstones, 1992). Grape quality for all wines is almost certainly reduced above an average mean temperature of about 24°C. The grape ripening period varies with growing season temperatures, and occurs during the months of July, August, and September.

Solar Radiation

Wine grapes require solar radiation for photosynthesis. High light intensity favors carbohydrate production via photosynthesis throughout the entire season; however it appears most beneficial during the spring and the period leading up to and at veraison or berry coloring (Gadille, 1976). According to Jackson and Lombard (1993),"In general high levels of radiation intensity or duration, result in increases in yield and /or sugar content''. Gladstones (1992) describes the influence of solar radiation on grape production as positive, provided temperature variability and relative humidity remain favorable.

The primary focus of AVATXIS is to integrates appropriate soil and climate data using spatial relationships as the key to enabling viticulturist to compare and contrast the factors/constraints that are important to grape production. In this section the soil, topography, and climate of each region will be described based on specific indices relevant to grapevine growth. This research does not attempt to make value judgments of the Texas AVAs, but rather systematically describes the key characteristics of the regions based on indices relevant to grapevine growth. The intuitive, user interface of AVATXIS allows any combination of these GIS layers to be rapidly retrieved and visualized through a standard web browser by any user of the system.

Description of Each Region

Bell Mountain

Geography

The Bell Mountain AVA is located in Gillespie County and is entirely contained within the Hill Country American Viticultural area. This is statistically the smallest American Viticultural area in the state, covering only approximately 6318.97 acres and located on the southwest slopes of Bell Mountain

Topography

This area is on the southwest slopes of Bell Mountain and elevations range from 505 meters to approximately 596 meters. The areas of highest elevation are located in the northern parts of the AVA with some areas of high elevations in the south. The central part of the AVA forms a valley between the areas of high elevation in the north and south. Several tributaries of the Colorado River, including the Llano and Pedernales rivers, cross the region west to east and join the Colorado as it cuts across the region to the southeast. These rivers drain to a large portion of the Hill Country thus having a tremendous effect on drainage in the region. The Guadalupe, San Antonio, Frio, and Nueces rivers originate in the Hill Country.

Soils

The region is dominated by 2 soil associations, Luckenbach-Pedernales-Heaton and Nebgen-Campair-Hye, with the latter covering over 50% of the region. Soil texture consists of clay and sandy loams at depths to 200cm with bedrock at depths greater than 200cm. The available water capacity of the area ranges from 13-25cm at depths of 100 to 250cm for the clay loam, while sandy loams range from 9-11cm at the same depths. The overall average AWC is approximately 15cm. The average pH of the Bell Mountain AVA is 7.10 and ranges from 6.6-7.80. The average soil depth of the region is approximately 112cm with an average permeability rate of 5.50cm/hr. Bulk density values in the area are 1.77g/cm^3.

Climate

The macroclimate in this region is influenced by the effects of the entire hill country as it is located in the heart of the Texas Hill Country. Figure 5 describes a typical year (1980) of temperature variation in Bell Mountain AVA and the climatic trends throughout the regions. The minimum temperatures are dominated by high diurnal variation in the winter months and more steady temperatures throughout the summer. The same pattern of variation in the winter months is experienced with mean temperatures which appear to be influenced by maximum temperature extremes in the summer months. Minimum temperature extremes and frost is experienced in March with temperatures dropping to as low as -10°C. Figure 5 describes the annual climatic trend of the Bell Mountain AVA.

The cumulative GDD in the Bell Mountain AVA ranges from 2764 to 2874 days °C. Higher solar radiation is experienced in higher elevations throughout the regions especially during the ripening period and fall months. Lower vapor pressure is exhibited in areas of low elevation in spring and early summer. Higher values of vapor pressure are experienced in the areas of lower elevation in the mid to late summer and during the ripening period months. The trend in number of frost days throughout the Bell Mountain AVA is greater number of frost days in areas of highest elevation. Annual precipitation values within the boundaries of the region ranged from 85-91cm with the most precipitation experienced during the month of September.

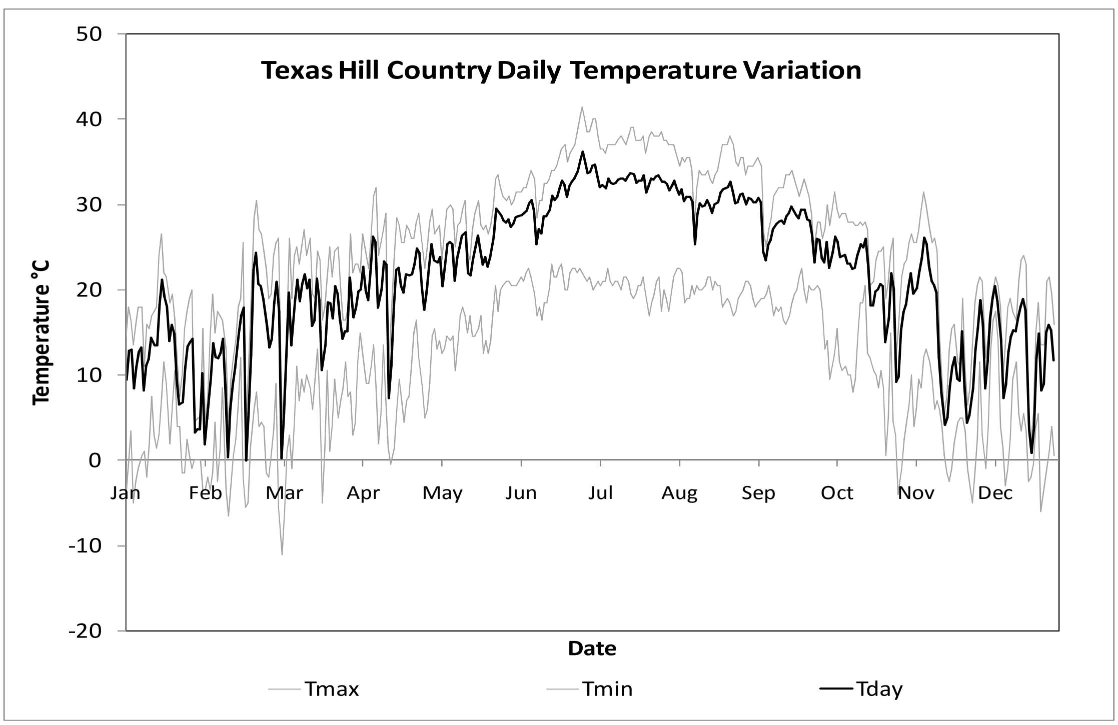

Figure 5 Typical daily temperature variation in the Bell Mountain AVA, 1980 (Fredericksburg,TX)

Texas Davis Mountains

Geography

This American viticultural area is home to the most extensive mountain range in Texas and the regions cover an area of approximately 313,724.63 acres.

Topography

The entire landscape is a segment of the southern Rocky Mountains and is mainly in Jeff Davis County. Locally called the Texas Alps, the area ranges in elevation from approximately 1100m to peaks as high as 2545m, the highest of which is Mount Livermore at 2500meters or 8200ft. The landscape is completely hilly with peaks and valleys throughout with higher elevations in the southwest..

Soils

The Davis Mountains AVA consists of 5 soil associations. Over 70% of the region is dominated by Rock Outcrop-Mainstay-Liv. Soil texture is predominantly silt loam and loam along areas of clay particularly at depths of 30-80cm. Most of this region is dominated by non-soil surface bedrock referred to as other. AWC ranges from values as low as 3cm to depths of up to 21cm while permeability rate is 5.44cm/hr. The average bulk density of the Davis Mountains AVA was 1.81g/cm^3. Soil depths in the Davis Mountains average around 143cm in areas dominated by clay and clay loam. Areas with silt loam and loams have depths of around 49cm. The overall average depth of the region is 87cm. Loams are neutral to basic with pH ranges from 7.00-7.40 while areas dominated by clay are more acidic with pH value of 5.40. The average pH in the region is 6.82 Figure 6 illustrates the geographic location of Davis Mountains and a soil texture type at depth of 80cm which is adequate for vine growth.

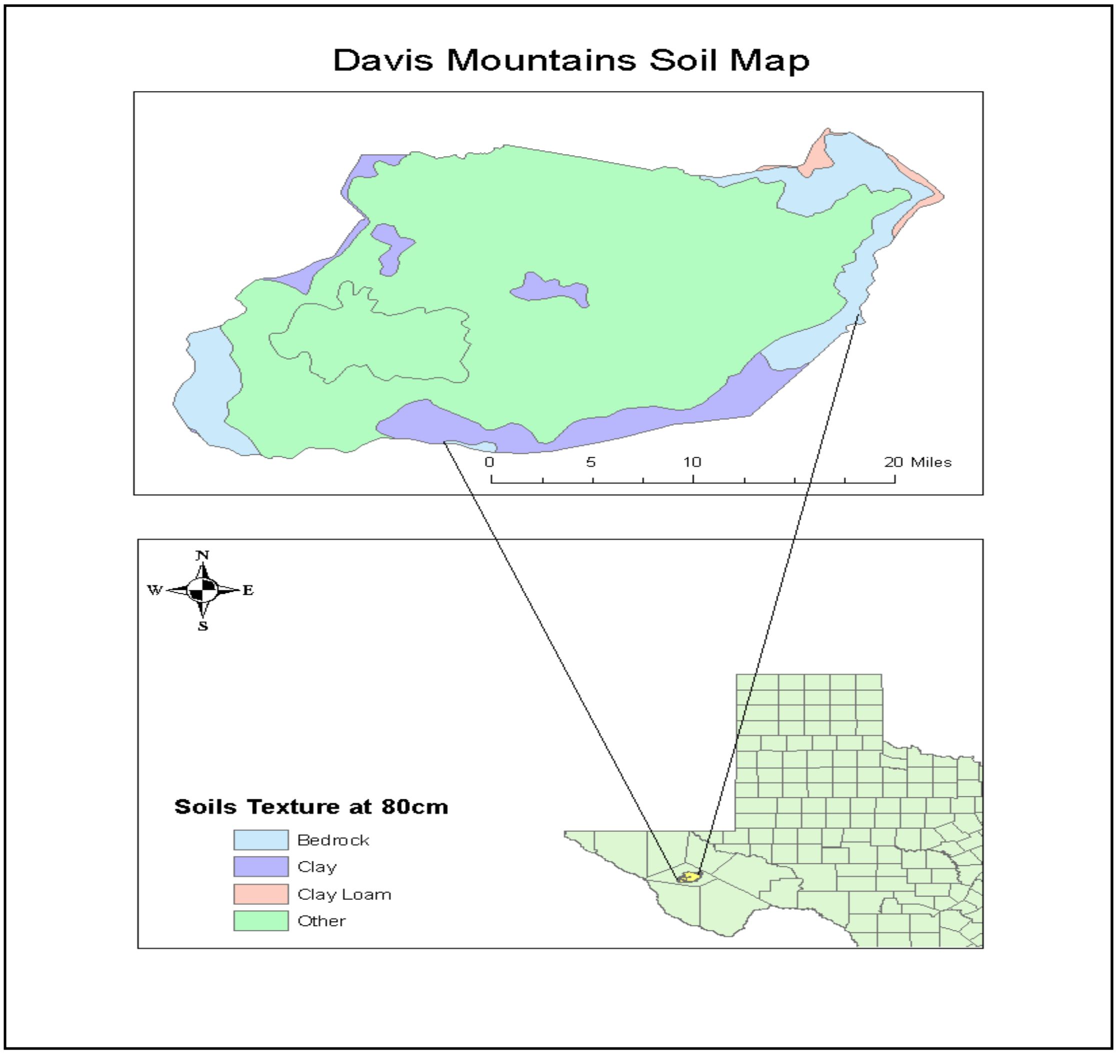

Figure 6 Location of Davis Mountain AVA and also depicted are soil texture types at 80cm of depth

The various soil associations located throughout the Davis Mountain AVA are outlined in figure 7. These associations simply aid in the classification of the soil types for further analysis and visualization using GIS. There is no significant implication beyond the mere classification of these different associations.

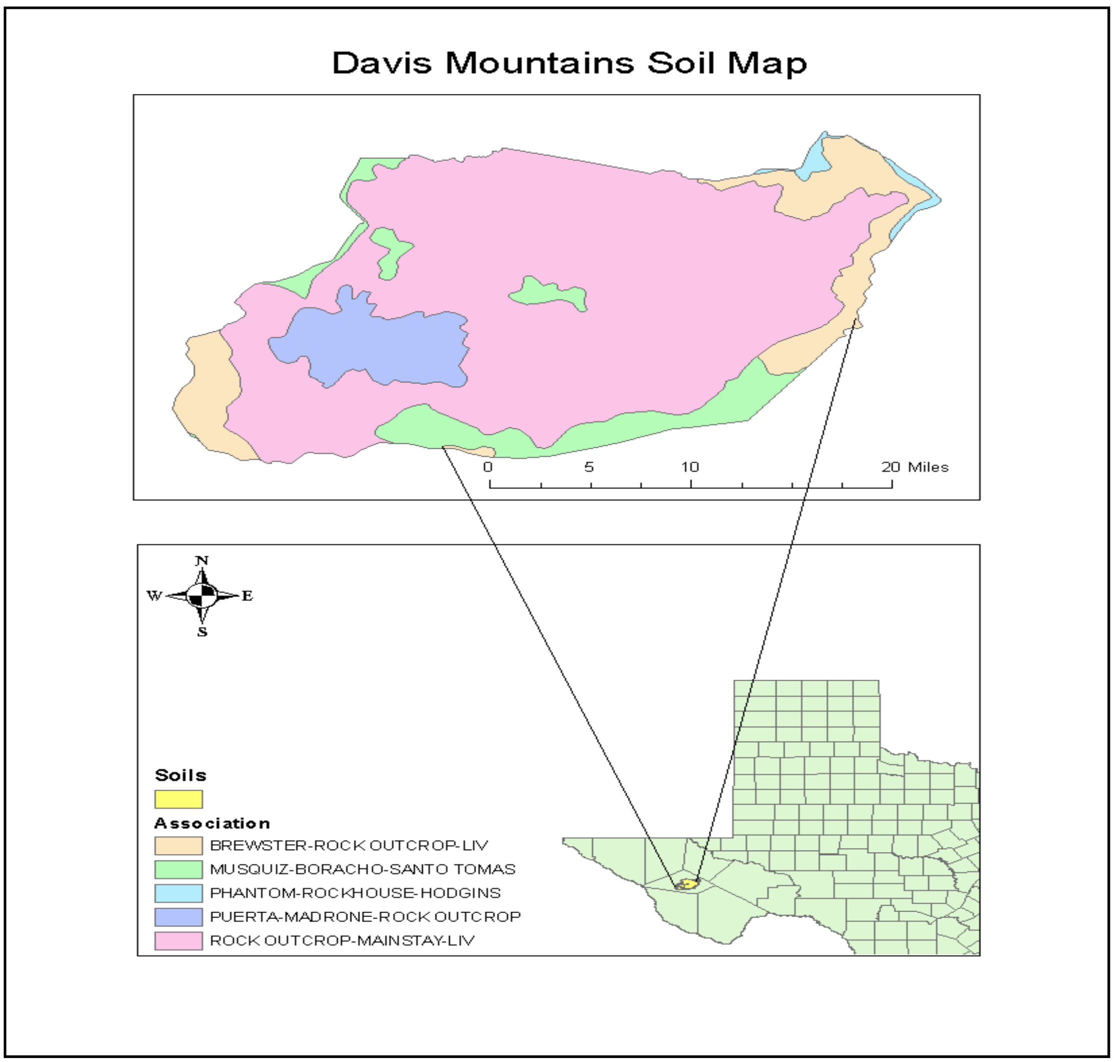

Figure 7 Location of Davis Mountain AVA and soil associations in region

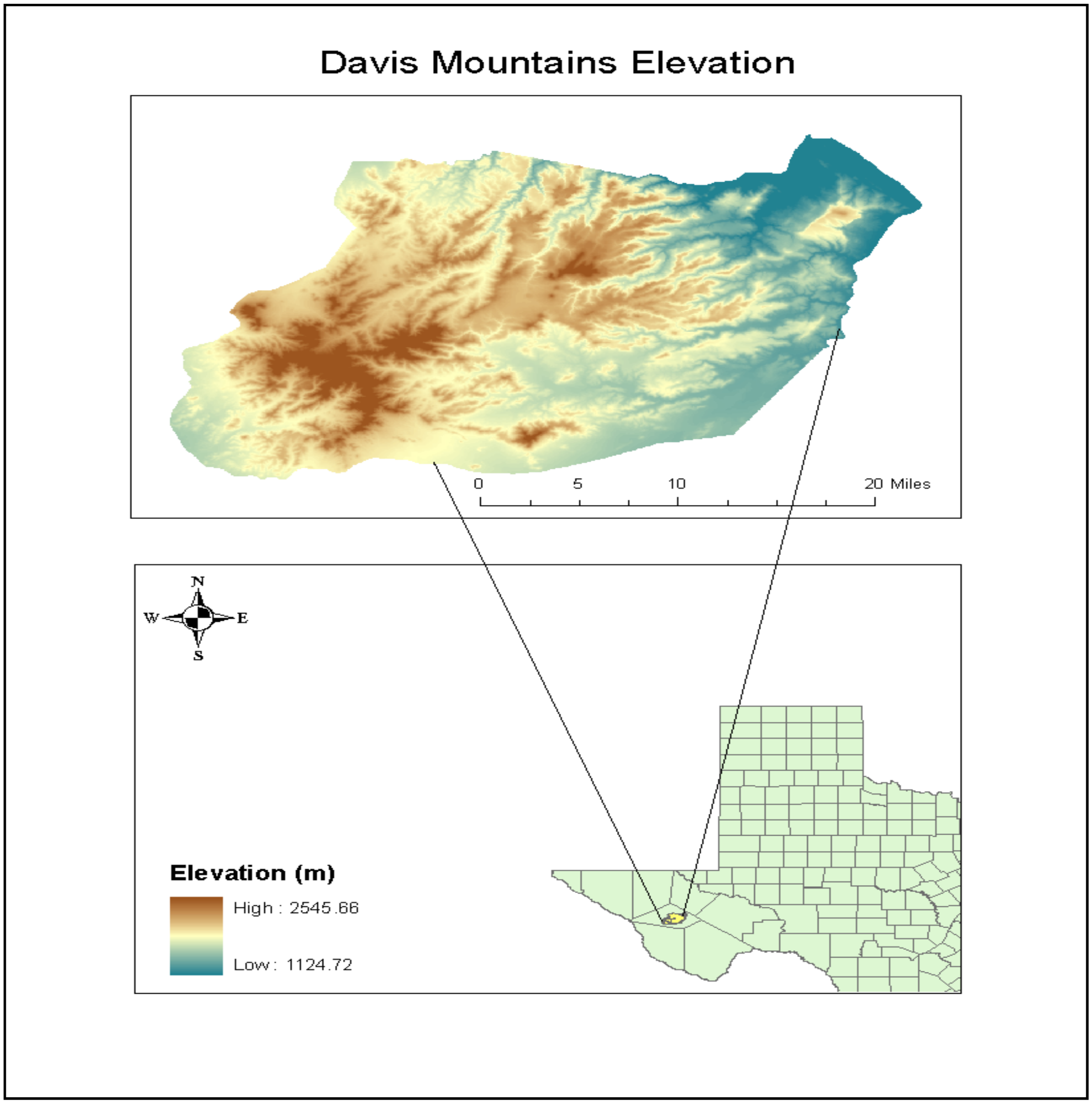

Figure 8 Elevation of Davis Mountain AVA

Climate

The climate of this region is the most moderate in Texas but minimum temperature in the winter months show tremendous variation (high diurnal fluctuation) with temperature extremes.Climate is influence by changes in elevation depicted in figure 8. Minimum in the summer is more steady averaging around 12-15°C. The average temperature seems to be driven by maximum temperature reading throughout the year. In the summer the average temperature is somewhat steady but again tremendous variation can be seen in the winter months. GDD values for the Davis Mountains AVA range between 1429 and 2672days °C. The is no apparent trend in solar radiation throughout the region Higher values of vapor pressure is experienced at lower elevations while areas of higher elevation exhibit lower vapor pressure. There is great variation throughout the region in number of frost days at higher and lower elevations throughout the Davis Mountains. Areas with higher elevations do exhibit greater number of frost days as compared to areas of lower elevation. Average annual precipitation range for the regions is approximately 36-49cm of rain with the greatest precipitation in the months of August through mid November. Greatest precipitation seems to be in areas of higher elevation. Figure 9 provides for a more clear description of the temperature variation in the region.

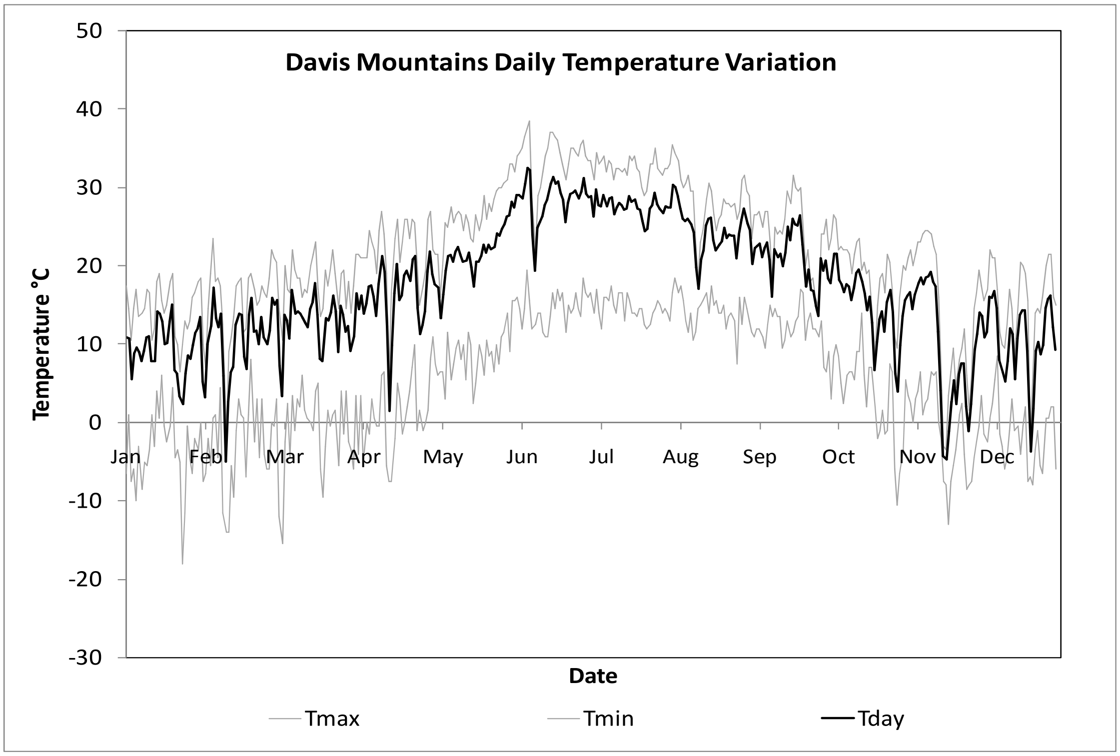

Figure 9 Daily temperature variations in the Davis Mountains

Escondido Valley

Geography

This viticultural area is located in Pecos County Texas and covers approximately 32,000 acres along Interstate highway 10.

Topography

The landscape of this American viticultural area is dominated by higher elevations in the south and considerably lower elevation in the north and northeast. The elevation ranges from 976m to 772m with an isolated peak at about 890m in the far north east end of the region.

Soils

Located in Pecos County, this American Viticultural Area is dominated by 3 soil associations with no distinct pattern of distribution. Soil associations include Ector-Rock Outcrop-Dev, Lozier-Rock Outcrop, and Reagan-Hodgins-Iraan Over 95% of the AVA's soil texture is loam and silt clay loam. According to Cass (1999) soils with adequate water- holding capacity give vine the greatest ability to tolerate periods of drought. The AWC ranges from 14-26cm at depths of 100-250cm in silt clay loam but are considerably less for loams, ranging from 2-5cm. Average AWC in this region is approximately 9cm. The average BD and permeability of the soils in the region are 1.43g/cm^3 and 6.14cm/hr respectively.

Bedrock is encountered at a depth of about 152cm for silt clay loam but approximately at 45cm for loams. Soil pH is fairly consistent throughout, ranging from 8.10 to 8.20 with an overall average pH of 8.15.

Climate

The dominant trend of very high variation of temperature (high diurnal fluctuation) in the winter months is prevalent for maximum, minimum and average temperature. The summer months show considerably less variation (low diurnal fluctuation) with minimum temperatures around 15°C, average temperatures around 31°C but maximum temperature values are as high as 40°C. Periods of extreme frost are experienced in mid March and late November along with some average temperature values in the spring dropping to almost 0°C. GDD values in Escondido ranged from 2767-3034 days ° C. Solar radiation is greatest in this region in areas at higher elevation while those areas at lower elevation experience less solar radiation. Vapor pressure values are generally higher in areas of lower elevation throughout the Escondido Valley AVA. The trend in frost days is such that, at higher elevations there are greater number of frost days experienced in the regions and fewer frost days at lower elevations. The annual precipitation of this region is approximately 34-38cm of rain with the most precipitation experienced during the month of August in the southern parts of the AVA. September and October also experience relatively high amounts of rainfall. Figure 10 illustrates daily temperature variation in the Escondido AVA during the year 1980.

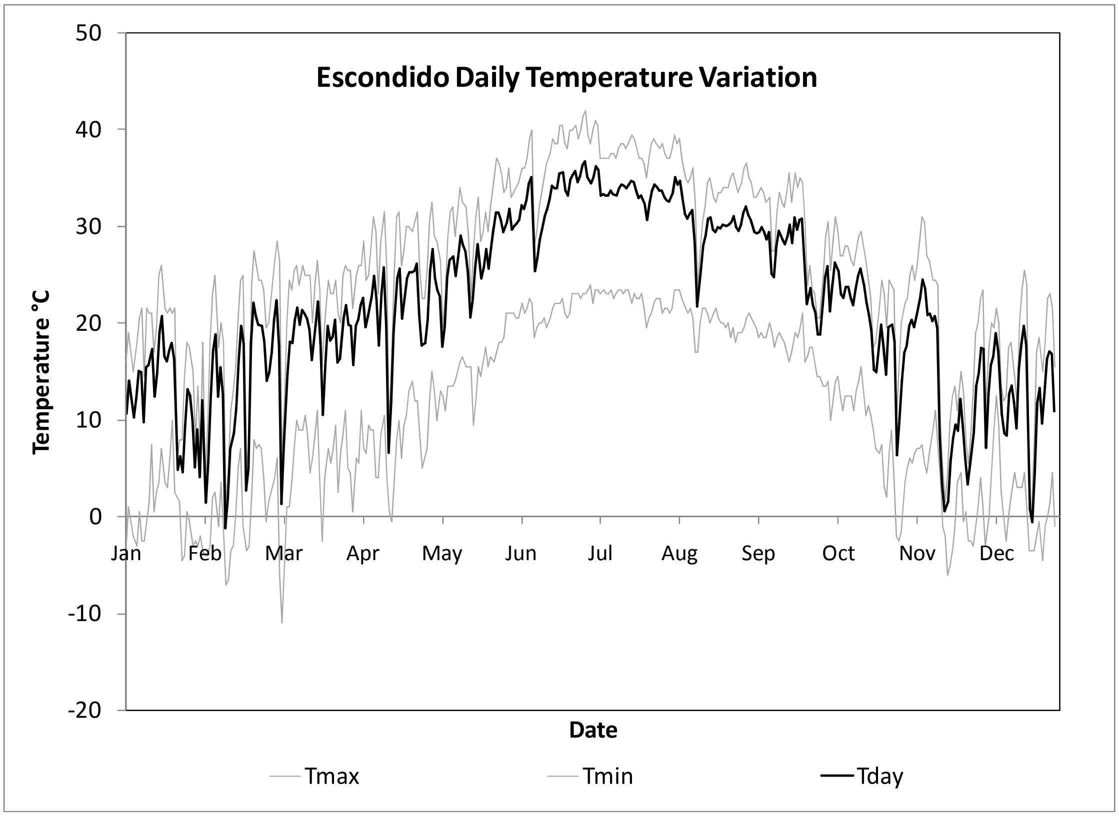

Figure 10 Daily temperature variations in the Escondido Valley AVA in the year 1980

Fredericksburg in the Hill Country

Geography

This viticultural area is located entirely in Gillespie County, covering over 66,708.82 acres and is part of the Hill Country AVA

Topography

As part of the Texas Hill country the topography is similar to the general topography of the entire region. This region is dominated by peaks and valleys with the elevation of the Fredericksburg AVA ranging from approximately 447m to 578m.

Soils

Fredericksburg in the Hill Country AVA consists of 4 different soil associations but is heavily dominated by the presence of Luckenbach-Pedernales-Heaton which occupies over 90% of the region. The texture is approximately 90% clay loam with the other 10% consisting mostly of loam, silty clay and clay. Instances of bedrock occur at depths greater than 200cm with sandy clay loam occurring at depths that range between 200 and 250 cm. AWC values are between 13 and 25cm for most of the area but dominated by clay exhibit AWC values around 5-6cm with an overall average AWC of 14cm. Permeability and bulk density values average at 3.38cm/hr and 1.72g/cm^3 respectively The average soil depth of the Fredericksburg viticultural area is approximately 107cm..

The average pH of the Fredericksburg AVA is 7.93 but values range from 7.10 to 8.20. With the vast part of the region being covered by clay loam, the majority of the AVA has an average pH value of approximately 7.41.

Climate

The climate of this AVA is really identical to the Hill Country AVA as it is part of and within the Texas Hill Country. Overall climatic trends within Fredericksburg are identical to those experienced in Bell Mountain AVA but the annual temperature within the boundaries of Fredericksburg ranged from 78-89cm. GDD values within the boundaries of this region are approximately 2743-2952days °C.

Figure 5 shows the daily variation in temperature for Fredericksburg, Texas which is part of the Hill Country. There is a general trend of higher solar radiation in areas of higher elevation throughout the region with high vapor pressure in areas of lower elevation. Areas of highest altitude experience a greater number of frost days as compared to those areas of lower elevation.

Texas High Plains

Geography

This is the second largest American Viticultural Area in Texas with 33 different soil associations to its credit, covering over 8,893,135.71acres. This region is located in the panhandle of Texas and depends on the subterranean Ogallala Aquifer, which spans almost the entire area underneath very well-drained soils.

Topography

The viticultural area shows great variation from west to east with the areas of the west at considerably higher elevations than the areas of the east. The low lying areas of the east exhibit elevations as low as 186m while areas of the western part of the High plains exhibit elevations as high as 1274m.

Soils

The Texas High Plains AVA has 33 distinct soil associations and this regions is covered by a mosaic of dominant soil texture types that exist within the region, including clay loam, clay, sandy loam, and sandy clay loam. These soil texture types cover over 55% of the region. The average AWC of the Texas High Plains AVA is approximately 22.78 in this very dry climate with the average permeability at 5.43cm/hr. The bulk density of the clay based soils of the High plains AVA is 1.52g/cm^3. The average depth to bedrock in the area is approximately 142.78 pH values range from 6.60 to 8.20. The overall average pH of this expansive AVA is 7.45.

Climate

Overall climatic trends of the High plains AVA are associated with variation in elevation from west to east. Minimum temperature in the winter months can be extreme and drop to values well below -12°C while values in the summer show much less variation (low diurnal fluctuation) and average around 15°C. Average temperature is influenced by maximum temperature with less variation in the summer months as compared to the winter months. Figure 11 displays the daily variation in weather of Lubbock Texas in the High plains during the year 1980.

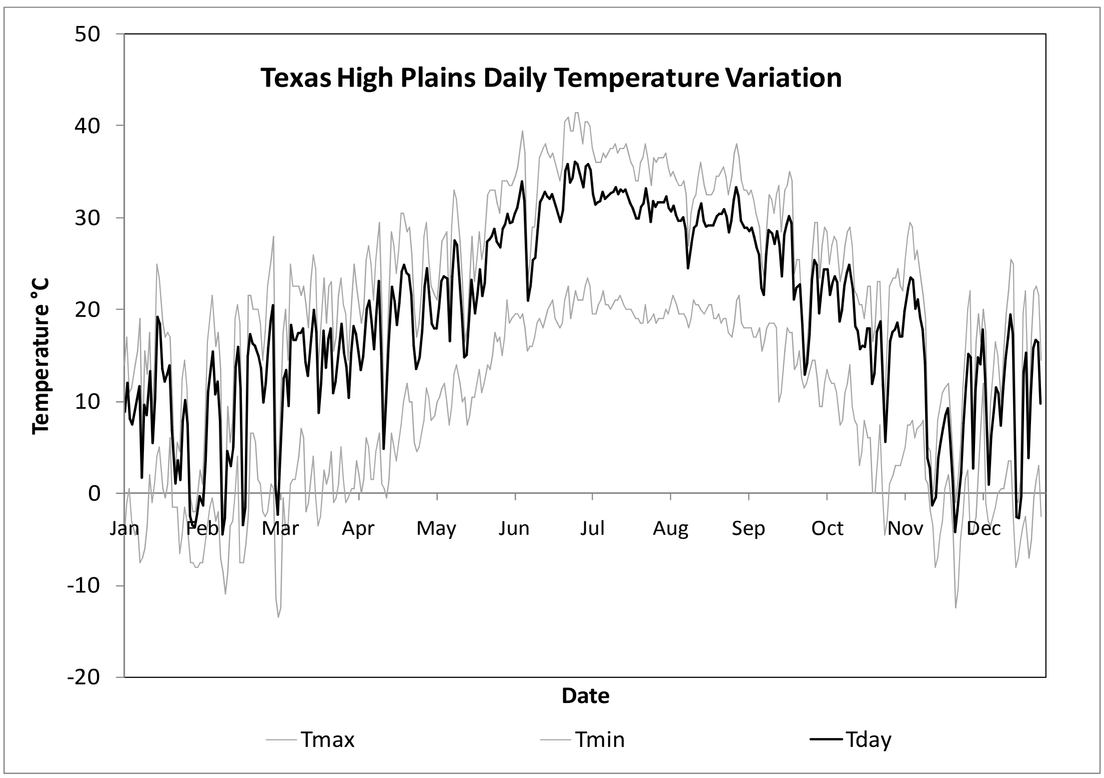

Figure 11 Daily temperature variations in 1980 for Lubbock, in the Texas high Plains

GDD values in the Texas High Plains range from 2027-2652 days °C Throughout the Texas high Plains AVA, areas at higher elevation exhibit higher solar radiation while those at lower elevations show less solar radiation. The general trend in the region is low vapor pressure at higher elevations and higher vapor pressure at low elevations. The number of frost days also varies with elevation as there is more frost days experienced at higher elevations. Given this trend, the northwestern part of the region is at a distinctly higher elevation and consequently more frost days. Average annual precipitation of the area is approximately 41-63cm. Figure 12 displays the typical daily variation in precipitation for Lubbock, in the Texas High Plains during the year of 1980.

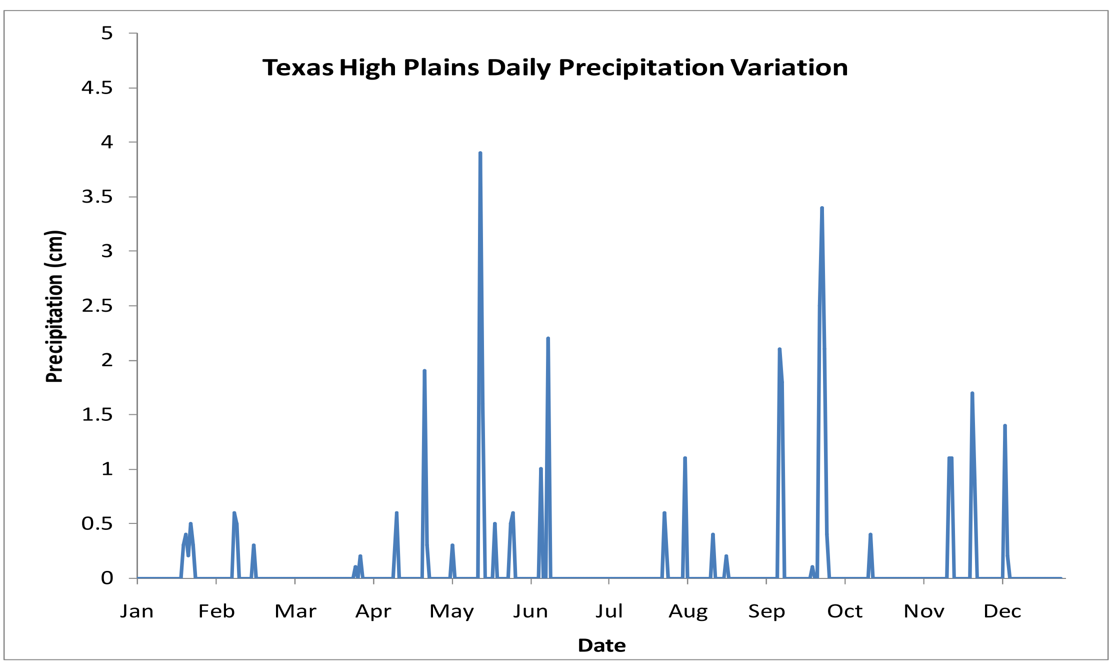

Figure 12 Daily variation in precipitation during 1980 for Lubbock in the Texas High Plains

Texas Hill Country

Geography

This is the largest viticultural area in the state and the second largest in the United States. Texas' largest AVA comprises 58 different soil associations distributed over an area of approximately 9,320,532.27acres.

Topography

This area sits on the Edwards plateau and it comprises many hills and steep canyons. The elevation ranges from 130-738m with the areas of lowest elevation in the south and north east end of the region. The central parts of the AVA and along the western edge are some of the areas of the greatest elevation.

Soils

There are 58 different major soils associations in the Texas Hill Country AVA and the major soil texture types in the hill country AVA include clay loam, clay, and sandy clay loam. With such a vast variety of different soil associations making up several different texture types, there is a wide range in values of AWC. This ranges from 2cm in some areas to as high as 34cm in others with an average value of approximately 16cm The average soil permeability rate of the region is approximately 2.73cm/hr with average soil bulk density of 1.65g/cm^3. The same large variation exists for soil depth; the low being

30cm and the high being 152cm with an average depth of 103cm. Average pH value of the soils is approximately 7.15 but values ranges from 6.20 to 8.10.

Climate

The minimum temperatures are dominated by tremendous variation (high diurnal fluctuation) in the winter months and more steady temperatures throughout the summer. The same pattern of variation in the winter months is exhibited by mean temperatures values in the summer months which appear to be influenced or dominated by maximum temperature extremes in the summer months. Minimum temperature extremes and frost is experienced in March with temperatures dropping to as low as -10°C. Figure 5 describes the climatic trend of the Hill Country AVA which is identical to the trends in Bell Mountain and Fredericksburg as they are wholly contained within the Hill Country.

The cumulative GDD in the Texas Hill Country AVA ranges from 2658 to 3377 days °C. Areas of higher elevation experience greater solar radiation throughout the year in the Texas Hill Country AVA and higher vapor pressure is experienced in areas at lower elevations. This region exhibits a clear trend of higher number of frost days associated with greater elevation but there is no significant difference in the range throughout the region. Annual precipitation values for the region ranged from 84-124cm with the most precipitation experienced during the month of September.

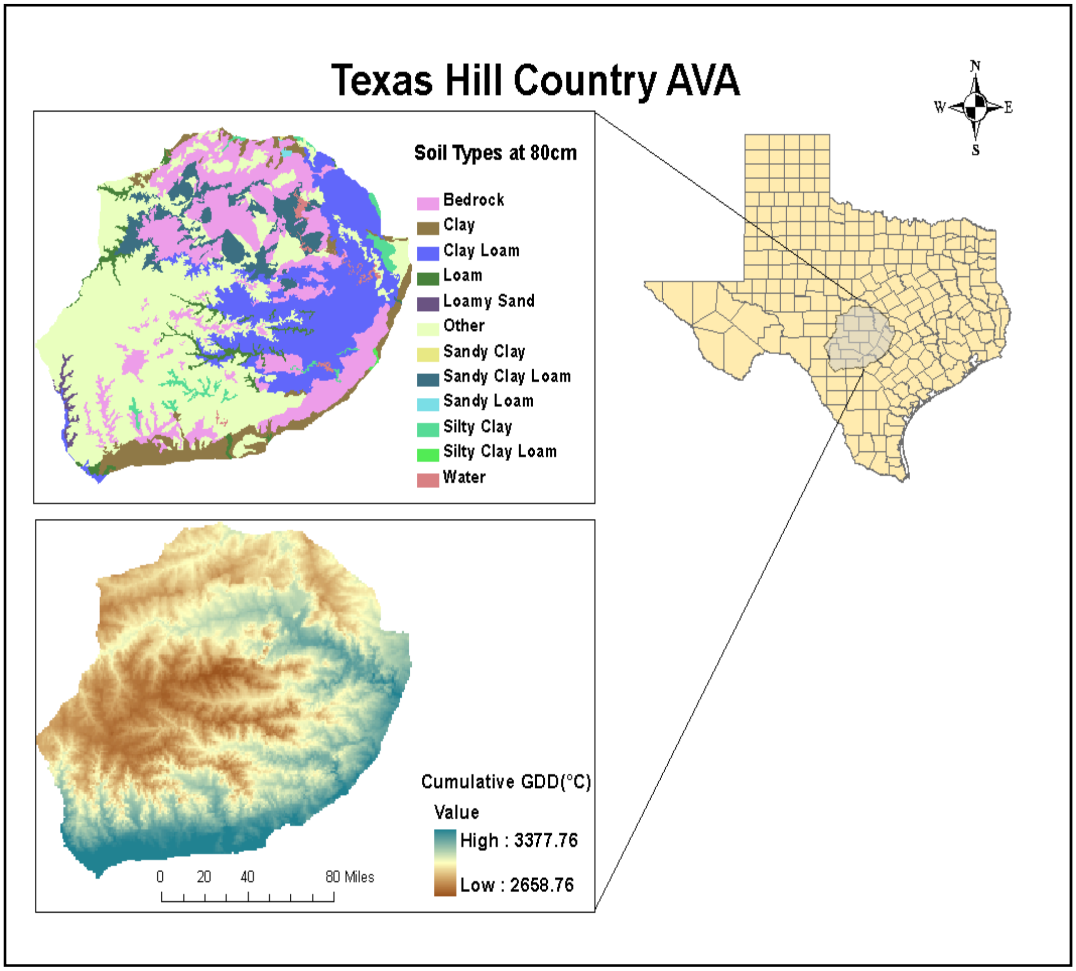

Figure 13 Location of the Hill Country AVA and also depicted are soil texture types at 80cm of depth along with distribution of GDD◦C

Mesilla Valley

Geography

This AVA is located in portions of New Mexico covering an area of 40,637.74 acres with 4 different soil associations. The Texas portion of the Mesilla Valley viticultural area is located north and west of El Paso within El Paso County

Topography

This AVA is relatively high in elevation especially along the eastern edge of the region. The elevation ranges from 1134-1302m with the lowest areas located to the extreme western portions of the AVA. The landscape is dominated by the Franklin mountains of El Paso and the Rio Grande river which flows southward through western Mesilla Valley and swings eastward through El Paso del Norte [Pass of the North] on the southeastern margin of the Franklins. It continues its eastward flow from there to the Gulf of Mexico.

Soils

This AVA has the following soil associations; Delnotre-Canutio-Nickel, Glendale-Armijo-Harkey, Pintura-Bluepoint-Wink, and Rock Outcrop-Brewster-Volco. The texture of the soils is mostly sand, loam, and clay loam but heavily dominated by sand and clay loam. The geographic distribution of the dominant texture types at a depth of 80cm are illustrated in figure 14. The average soil depth of the Mesilla Valley AVA soils is 125cm with bulk density values of 1.65g/cm^3 AWC ranges from 3cm to 19cm in some areas while overall average AWC is 9.83cm and permeability rate averages at11.81cm/hr. The pH values in this AVA are very basic with a range between 7.60 and 9.0; average value for soil pH in this region is approximately 8.06.

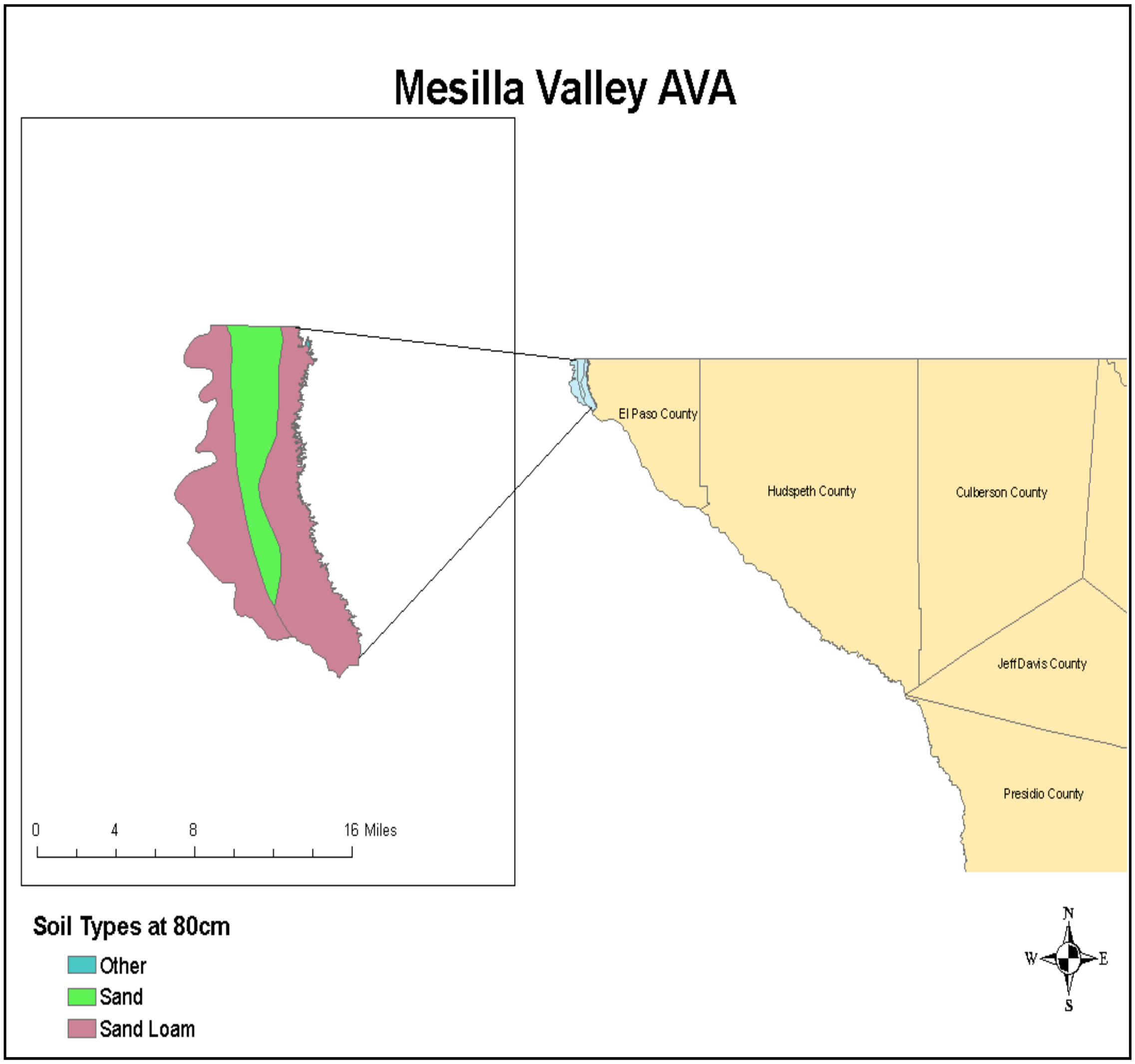

Figure 14 Location of the Mesilla Valley AVA and soil texture types at 80cm of depth

Climate

The climate in Mesilla Valley AVA is characterized by moderate variation of minimum temperature in the winter months followed by more gradual fluctuation of temperature minimums in the summer months. The values for minimum temperature in the winter drop as low as -9°C and as high as 8°c in mid February. The average temperature readings in the winter months show tremendous variation. There are often periods where days are relatively warm and nights are extremely cold. During the summer months there is less variation, but values seem to be again influenced by maximum temperatures. Maximum temperature values in the winter months are well above 20°C while summer months are extremely hot. Readings in the summer are as high as 40°C from mid June to early August. Figure 15 shows temperature variation for Anthony, Texas located in the Mesilla Valley AVA during the year 1980.

The GDD in the region ranges from 2480 to 2849 days °C. There is more solar radiation experienced in the north and western parts of the AVA with no visible trends that can be attributed to elevation. There is high vapor pressure during the ripening period months in areas of higher elevation. High vapor pressure is also experienced in early spring and summer in areas of lower elevation. Even though areas in the east at higher elevations have more frost days, there is not much difference in the total number of frost days over the entire region. The average annual precipitation is the lowest of all Texas AVAs and ranges from 20-29cm with the greatest precipitation experienced in the eastern parts of the region

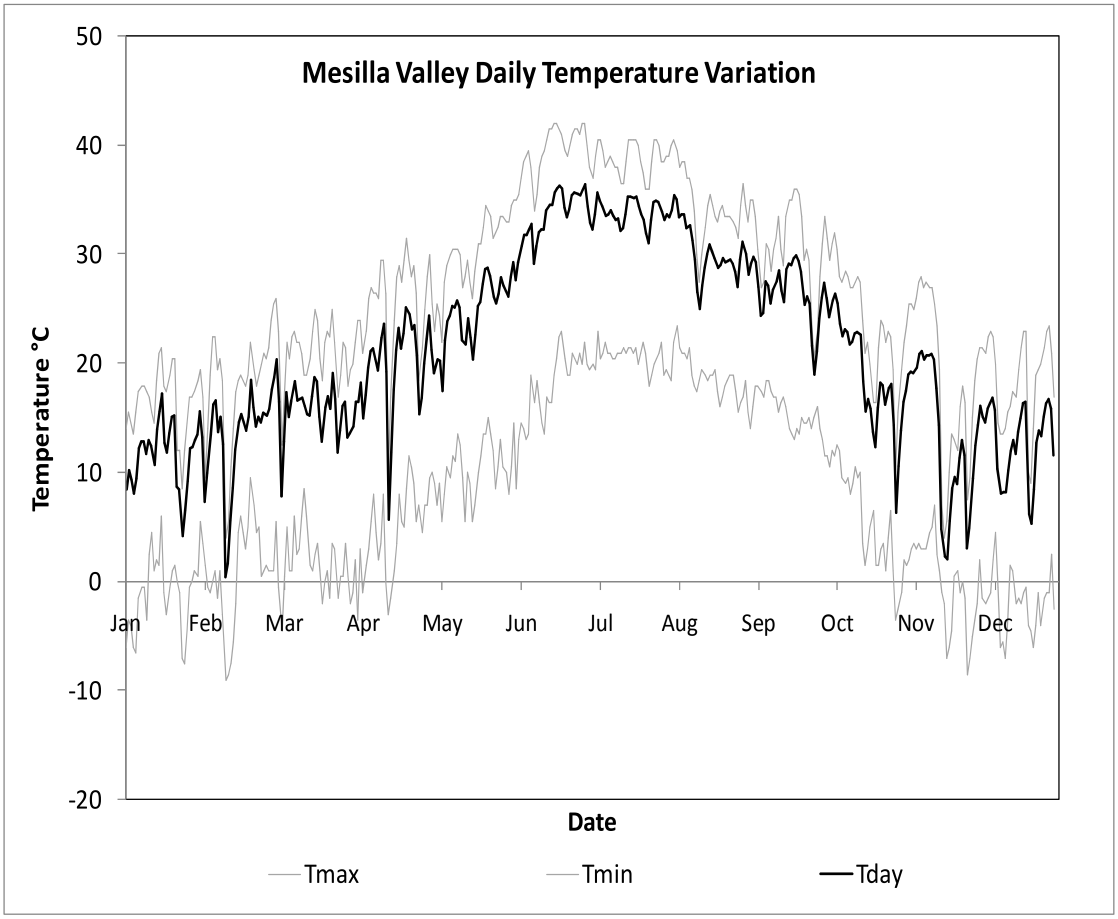

Figure 15 Temperature variation for Anthony, Texas located in the Mesilla Valley AVA during the year in 1980

Texoma

Geography

The regions cover approximately 2,152,715.58 acres on the south side of manmade Lake Texoma and the Red River, which both lie along the Texas-Oklahoma state line. This is the most recently established AVA in Texas.

Topography

The landscape of the Texoma AVA slopes northward towards the Red River. The elevation ranges from a low of 129m in the north east to a high of 402m on ridges in southeast Montague County. Lake Texoma and the Red River are two prominent water bodies in the area.

Soils

There are 24 different soil associations randomly distributed throughout the Texoma AVA. The texture of soils in this region consists mostly of sandy loam, silty clay loam, and clay. There is a broad range of values for AWC ranging from 6cm to 32cm which may be attributed to the wide array of different soil associations in the region. The average soil permeability is 2.48cm/hr. and soil bulk density is 1.59g/cm^3 in the region. The average soil depth is approximately 128.58cm and Figure 16 shows a complete list of the various soil texture types in the Texoma AVA. This depiction of soil texture type is at a depth of 80cm.

The average pH values of approximately 6.81. The pH range of 5.30 to 8.20 is rather broad and more acidic than other AVAs but may also be attributed to the number of different soil associations located in the Texoma AVA.

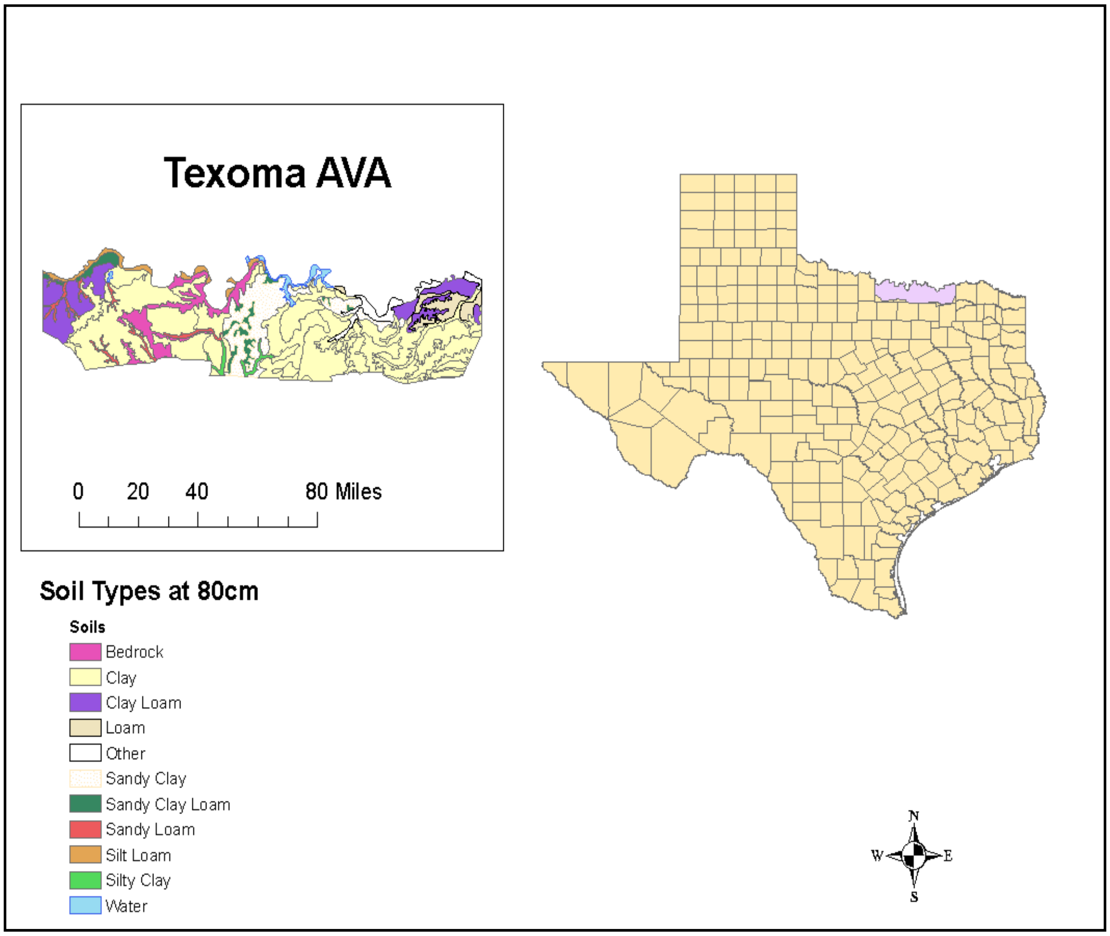

Figure 16 Location of the Texoma AVA and soil texture types at 80cm of depth

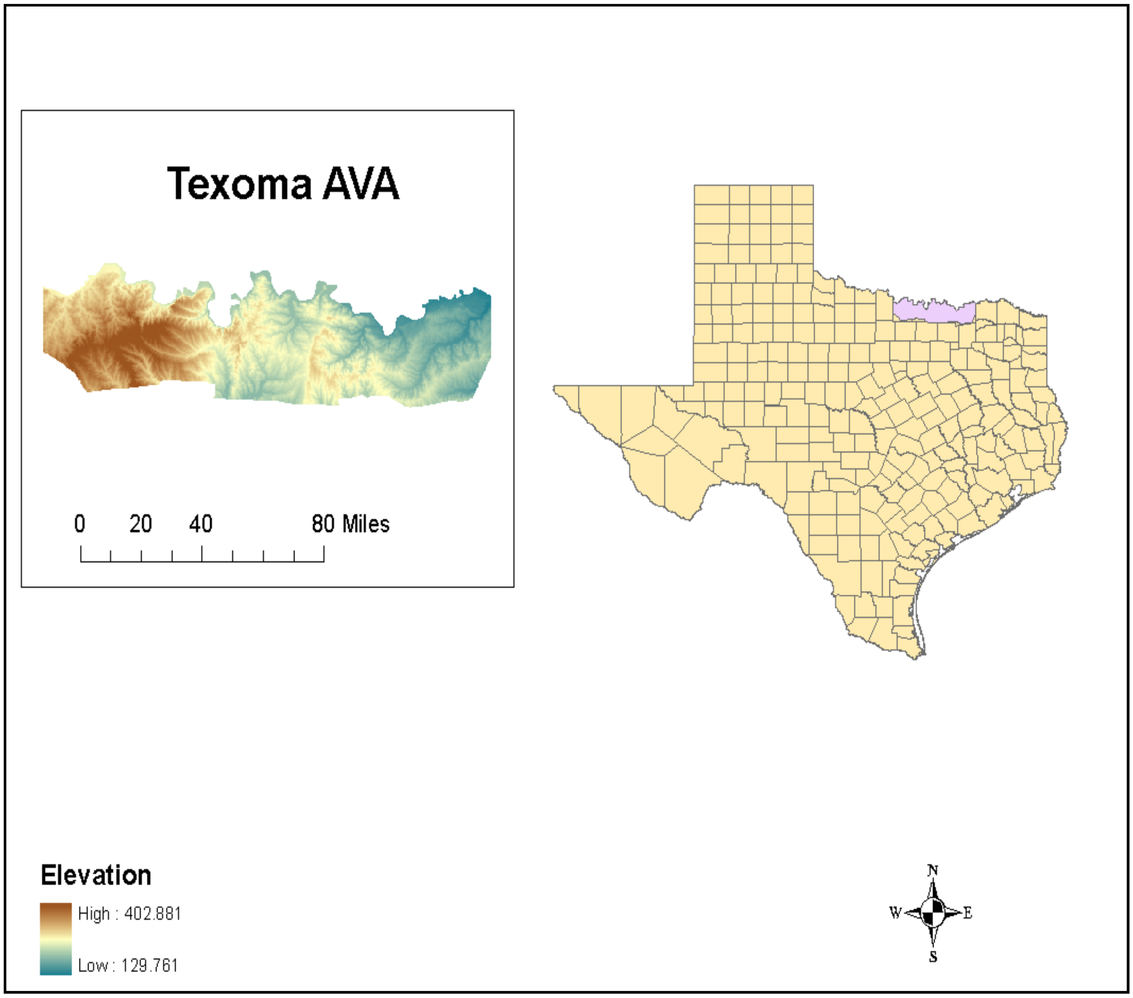

Figure 17 Location of the Texoma AVA and variation in elevation across the region

Climate

The minimum temperature readings during the winter months are drop as low as -10°C with highs around 11°C. The summer months exhibit much less variation with readings from 15° to 21°C. Average temperature in the winter months again show quite a bit of variation dropping below 0°C but highs are often well above 20°C. The summer months show slight, if any variation with temperature fluctuating around 33°C. Maximum temperature readings for winter months also show a fair degree of variation while summer months exhibit relatively less.Climate trends may be a function of elevation variation in the region, which is depicted in figure 17. Figure 18 displays daily temperature variation in Sherman, located in the Texoma AVA during the year 1980. This depicts a typical year of daily temperature variation in the area.

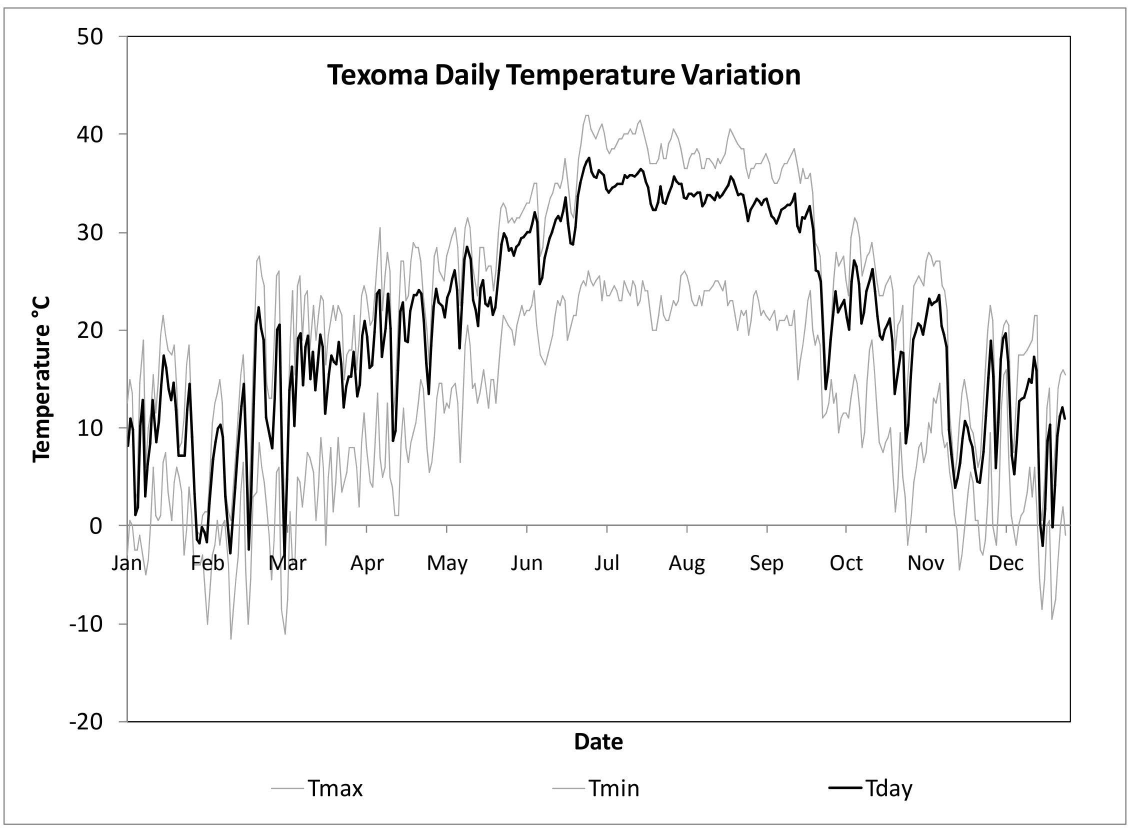

Figure 18 Daily temperature variations for Sherman in the Texoma AVA during 1980

The GDD values for the Texoma AVA range from 2767 to 2970 days ° C. The general trend in the region is greater solar radiation in areas of higher elevation This trend does not seem to hold during the months of August and September as areas of low elevation have values of solar radiation similar to regions at higher elevations. During the spring months and early summer, there is low vapor pressure in areas of higher elevation and high vapor pressure in areas of low elevation. This trend is not followed in late summer and early fall as lower vapor pressure is observed in areas of both high and low elevation The number of frost days follow elevation trends with the eastern part of the region showing fewer frost days due to lower elevation and greater number of frost days in the west where elevation is much greater. The average annual precipitation of this AVA displays a distinct east to west trend with higher precipitation values in the far eastern parts of the regions and lower values in the west and North West. The range for precipitation in the region is 84-124cm annually which is one of the highest of all the Texas AVAs.

CHAPTER V

OVERVIEW OF AVATXIS

Overview of Web-based System

AVATXIS is a spatial information management system. It enables access to information sources that provide a better understanding of edaphic and climatic factors of wine growing regions and assist with the decision-making process involved with vineyard management.

The primary purpose of any information management system is to provide users with information that is complete, accurate, and in real-time (Obermeyer and Pinto 1994). The advent of the Internet has led to easy access to vast amounts of information, yet the ability to integrate these large data sets for meaningful analysis is often not so obvious. This tool provides users with a useful and effective means of acquiring large amounts of data for further spatial and temporal analysis.

The application allows users to spatially query and visualize a range of edaphic and climatic factors that influence vine growth and grape production. The basic framework of the system consists of a main page that allows users to choose one of the 8 wine regions for further descriptive analysis based on the available factors of climate, soil, and topography.

The foundation technologies used by AVATXIS are all industry standard software and hardware. This system delivers dynamic maps and GIS data related to the aforementioned factors as ArcIMS services via the Web. The ArcIMS framework consists of clients (users of the system), services (8 different services representative of each of the Texas AVAs), and data management (climate, soil and topographic factors). Users can access AVATXIS via the Internet using a standard web browser. AVATXIS' software architecture allows direct customization at all levels. At the client level, custom HTML and JavaScript were used to modify the look and feel of the viewer (maps which clients ultimately see). At the server level, ArcXML was used to modify map configuration files or MXDs (to project data, define the appearance of map features, and so on).

AVATXIS is not just a tool but it is a framework for sharing information about the climate, soil and topographic characteristics of the Texas wine regions that are influential to grapevine growth. It allows users to illustrate relationships, connections and patterns in data that would otherwise not be analyzed due to the cumbersome nature of the data. The unique integration capabilities of AVATXIS brings together data from many sources for visual display and analysis, thus better describing the wine regions and providing a more complete depiction of the Texas AVAs. This enables wine growers to better describe the Texas AVAs based on all the relevant factors.

Figure19 illustrates the main page to AVATXIS while figure 20 shows a sample AVA which is accessible beyond the main page. Various soil factors can be obtained in table format from AVATXIS by clicking on the soil layer. Figure 21 illustrates a downloaded data table from AVATXIS looks like, as well as the information available to the user.

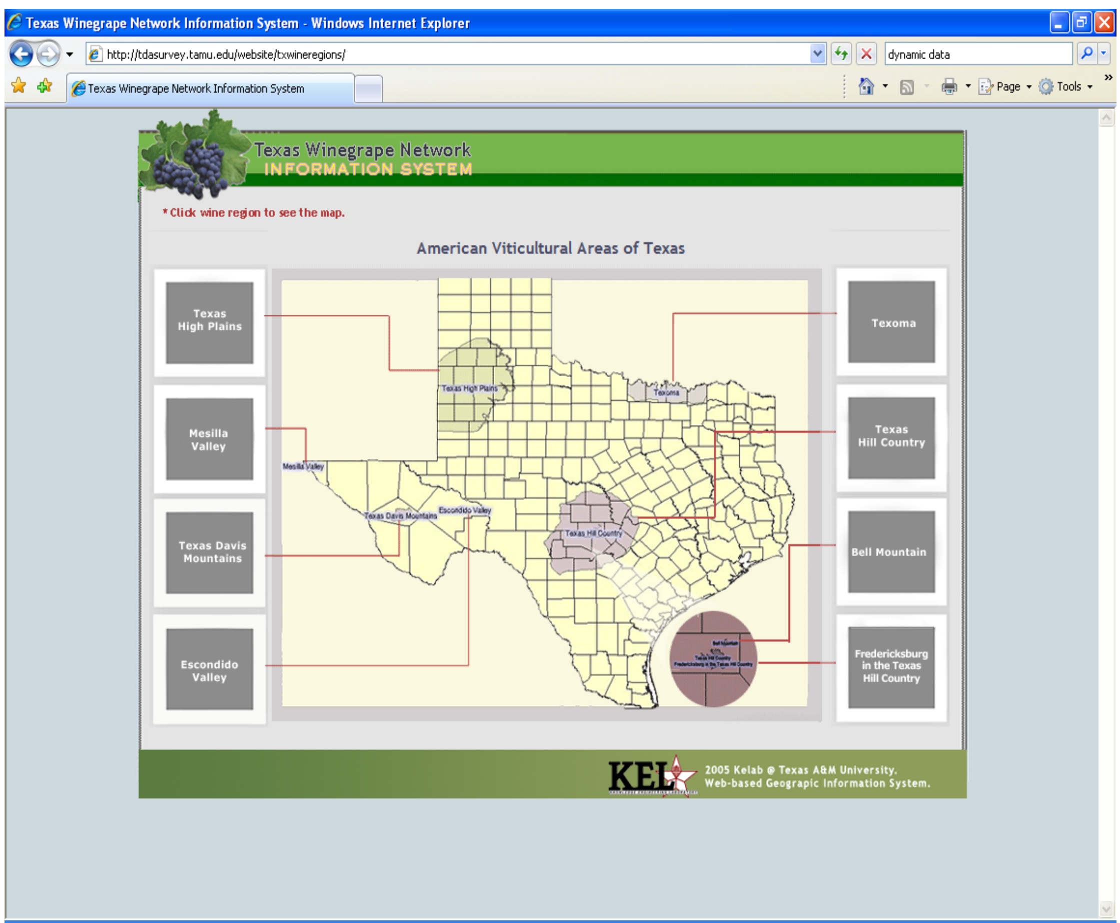

Figure 19 Main page of AVATXIS

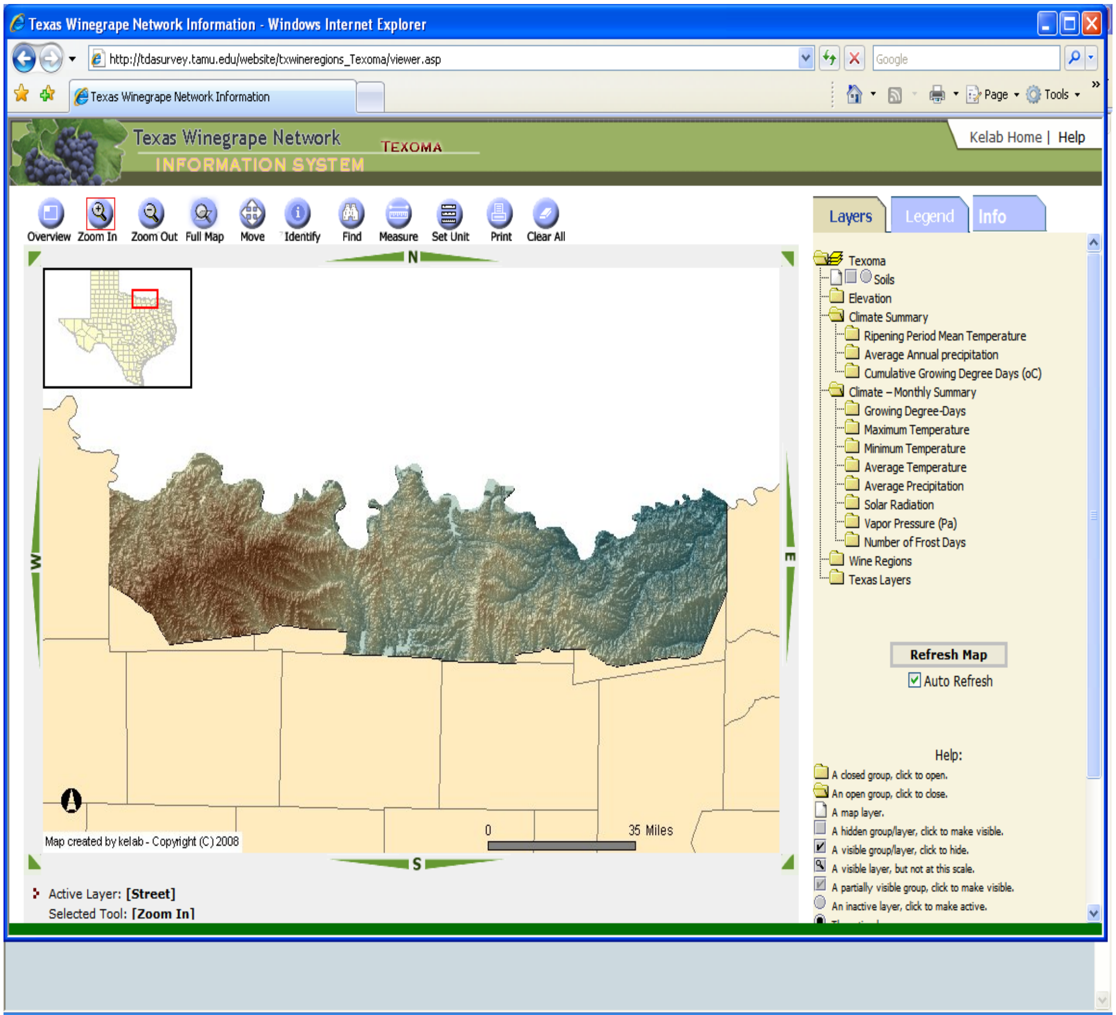

Figure 20 Main page to the Texoma AVA

Query/Selection Results - Windows Internet Explorer

about:blank

Soils

Rec	MUID	ASSOCIATIO	AREA_HECTA	AREA_ACRES	TEX_CM_5	TEX_CM_10	TEX_CM_20	TEX_CM_30	TEX_CM_40	TEX_CM_60	TEX_CM_80	TEX_CM_100	TEX_CM_150	TI
1	TX008	ALEDO-BOLAR-BRACKETT	21768.71	53790	Clay Loam	Clay Loam	Clay Loam	Clay Loam	Clay Loam	Bedrock	Bedrock	Bedrock	Bedrock	
2	TX024	ANNONA-FREESTONE-WOODTELL	282.08	697	Loam	Loam	Loam	Sandy Loam	Clay	Clay	Clay	Clay	Clay Loam	
3	TX032	AUBREY-KONSIL-BIROME	18905.19	46715	Sandy Loam	Sandy Loam	Sandy Loam	Clay	Clay	Clay	Sandy Clay Loam	Other	Other	
4	TX034	AUSTIN-HOUSTON BLACK-HEIDEN	785.52	1941	Clay	Clay	Clay	Clay	Clay	Clay	Clay	Clay	Clay	
5	TX063	BONTI-EXRAY-TRUCE	28349.2	70051	Sandy Loam	Sandy Loam	Sandy Loam	Clay	Clay	Clay	Clay	Bedrock	Bedrock	
6	TX084	CALLISBURG-GASIL-AUBREY	89586.12	221367	Sandy Loam	Sandy Loam	Sandy Loam	Clay	Clay	Clay	Sandy Clay	Sandy Clay	Sandy Clay	
7	TX099	CLAIREMONT-YOMONT-MANGUM	14365.6	35497	Silt Loam	Silt Loam	Silt Loam	Silt Loam	Silt Loam	Silt Loam	Silt Loam	Silt Loam	Silt Loam	
8	TX178	FAIRLIE-DALCO-CROCKETT	91998.64	227329	Silty Clay Loa	Silty Clay Loa	Silty Clay Loa	Silty Clay Loa	Clay	Clay	Clay	Clay	Silty Clay	
9	TX193	FRIO-TINN-OVAN	7952.48	19651	Silty Clay Loa	Silty Clay Loa	Silty Clay Loa	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	
10	TX226	HEIDEN-FERRIS-ALTOGA	91900.5	227086	Clay	Clay	Clay	Clay	Clay	Clay	Clay	Clay	Clay	
11	TX236	HOUSTON BLACK-LESON-HEIDEN	10439.51	25796	Clay	Clay	Clay	Clay	Clay	Clay	Clay	Clay	Clay	
12	TX243	IVANHOE-KARMA-DERLY	32366.48	79978	Loam	Loam	Loam	Loam	Clay Loam	Clay Loam	Clay Loam	Clay Loam	Clay	
13	TX251	KAUFMAN-TINN-GLADEWATER	1799.5	4447	Clay	Clay	Clay	Clay	Clay	Clay	Clay	Clay	Clay	
14	TX353	MOTLEY-BASTROP-TELLER	8711.1	21525	Loam	Loam	Loam	Sandy Loam	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam	San
15	TX425	PONDER-SANGER-SLIDELL	45128.21	111512	Clay Loam	Clay Loam	Clay	Clay	Clay	Clay	Clay	Clay	Clay	Silt
16	TX436	PULEXAS-GOWEN-BOSQUE	18765.13	46369	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	
17	TX442	PURVES-DUGOUT-MALOTERRE	29394.35	72633	Clay Loam	Clay Loam	Clay Loam	Clay	Clay Loam	Bedrock	Bedrock	Bedrock	Bedrock	
18	TX510	SEVERN-BILLYHAW-OKLARED	20338.03	50255	Clay	Clay	Clay	Clay	Other	Other	Other	Other	Other	
19	TX533	STONEBURG-ANOCON-KIRKLAND	53343.26	131811	Loam	Loam	Loam	Loam	Loam	Clay Loam	Clay Loam	Other	Clay	
20	TX559	TINN-FRIOTON-DELA	15425.78	38117	Clay	Clay	Clay	Clay	Clay	Clay	Clay	Clay	Clay	
21	TX600	WHAKANA-VESEY-RUSTON	28241.51	69785	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Loam	Loam	Sandy Clay Loam	
22	TX612	WINDTHORST-DUFFAU-BUNYAN	99131.18	244953	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Clay	Clay	Clay	Clay	Sandy Clay Loam	San
23	TX633	CROCKETT-WILSON-GOWEN	124517.68	307683	Sandy Loam	Sandy Loam	Sandy Loam	Clay	Clay	Clay	Clay	Clay	Clay Loam	
24	TXW	WATER	10340.03	25550	Water	Water	Water	Water	Water	Water	Water	Water	Water	

Zoom to these records

Internet 100%

Figure 21 Sample data table of soil layers generated by AVATXIS for Texoma AVA

CHAPTER VI

FUTURE WORK

The overall goal of this project was to develop a computer- based application, the American Viticultural Areas of Texas Information System (AVATXIS) ,that integrates, analyses, interprets, and displays information associated with each of the 8 Texas wine regions for potential vineyard site selection. This goal was achieved by meeting the following objectives:

- Characterize the Texas wine regions based on physical characteristics including soil, climate, and topography.
- Develop a web based GIS to deliver information associated with the above mentioned factors.
- Integrate, display and analyze edaphic and climatic factors that affect the performance of vineyards.
- Provide a spatial information tool that allows wine growers to better understand their growing regions, along with the edaphic and climate factors that influence grapevine growth and fruit production.
- Provide access via the Internet to AVATXIS thus providing security for the database.

Each region was carefully described based on soil, climate and topographic factors showing the relevance of the various factors to grapevine growth. AVATXIS was developed and configured, thus allowing any combination of these GIS layers to be rapidly retrieved and visualized through a standard web-browser by any user of the AVATXIS system. Even though the system lends unique capabilities of spatial and quantitative analysis of excessive amounts of data, (climate, soil, and topographic indices) improvements upon the basic framework can be made.

Automated processes would greatly enhance the analysis of raw data sets such as repeated calculations of GDD and clipping of climate variable grids to the various regions. Manually created layers from raw data are sources of error and require tremendous amounts of time. Scripts that run these processes repeatedly can eliminate or minimize the occurrence of errors in analysis and calculations.

The use of dynamic as opposed to static or stored data is one of the main areas for improvement. A static data structure lends to data sets which do not change within the scope of the problem, hence limiting the scale of the tool to the prescribed extent. When a new factor is to be added or deleted, the update of a static data structure incurs significant costs, often comparable to the construction of the data structure from scratch. A dynamic data structure on the other hand allows for efficient updates when new factors are inserted or deleted.

Today's computers and software provide extraordinary computational abilities; hence expansion upon the basic frame of AVATXIS can readily be accomplished.

The major aim of the project is to integrate viticultural variables into a user-friendly tool that allows users to explore the spatial and temporal characteristics of the Texas wine regions. It is worth acknowledging that new technology may exist that allows much better integration between users and the underlying data. Examples of such technology include ESRI’s Arc Server, Virtual Earth, and Google Earth® etc.

Other potential expansions of the system would involve the evolution of a site selection tool. This would involve the inclusion of more indices relevant to site selection such as grape varietal information. Information about incorporation of management practices as well as incidents of pest and disease such as Pierces disease could also be useful. Expanding the spatial extent of the tool to include regions beyond Texas as well as extending beyond grapevine growth may also enhance the utility of the system.

CHAPTER VII

CONCLUSIONS

The objective of this study was to develop a web-based information system to help grape growers and wine makers understand the Texas growing regions. Climatic conditions, soil properties and topographic factors relevant to successful grapevine growth and fruit production were identified for specific use in the description of the Texas AVAs.

AVATXIS enables integration of vast amounts of climate, soil and topographic data for analysis and description of the Texas wine regions. This data in its current state can now be queried spatially using any standard web browser and quickly visualized. Publicly available climate data was used to create novel GIS layers for indices that include monthly summaries of maximum, minimum and mean temperature; precipitation and Growing Day Degrees. Available soil data was used to create GIS layers representing simple soil indices (pH, soil texture, depth to bedrock, permeability, available water capacity, and bulk density) useful to the wine grower. These climate and soils data make up the central database used by AVATXIS to integrate these factors particularly using spatial relationships as the key to allowing viticulturist to compare and contrast the factors/constraints that are important to grape production in the Texas wine regions. The user was able to determine the size of the region, various soil associations, soil texture, pH, AWC, bulk density, depth of soil and permeability. Climate information such as the growing season (GDD), temperature maximums, temperature minimums, average temperature, annual precipitation as well as elevation of the various regions is also available to the user.

Users of this system will gain a better perspective of the regions with regards to indices specific to grapevine growth. Analysis /description of the Texas AVAs both spatially and temporally by integrating soil, climate and topographic factors through the use of a web-based system allows users access to the Texas wine regions in real time. The simplicity of quantitatively and qualitatively accessing large and cumbersome amounts of data is one of the key benefits to AVATXIS.

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VITA

Elvis Arrey Takow was born in the small West African country of Cameroon. In 1980 the family moved to Baton Rouge, Louisiana where Elvis attended school for 3 years while his Dad attained his M.S. in Agronomy from LSU. The family briefly moved back to Cameroon and later moved to College Station, Texas in 1987 where his Dad completed his Ph.D. in soil chemistry in 1991.

In the spring of 2000, Elvis enrolled in Texas A&M University and obtained his B.S. in Renewable Natural Resources from Texas A&M University in May of 2004. Elvis later enrolled in the Department of Ecosystem Sciences and Management to pursue his M.S. in Rangeland Ecology and Management with an emphasis in Geographic Information Systems (GIS). While attaining his bachelor degree, Elvis' interest in Information technology and GIS grew thus he decided to focus his graduate interest and research in area of GIS. He obtained his Master of Science degree in December 2008.

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