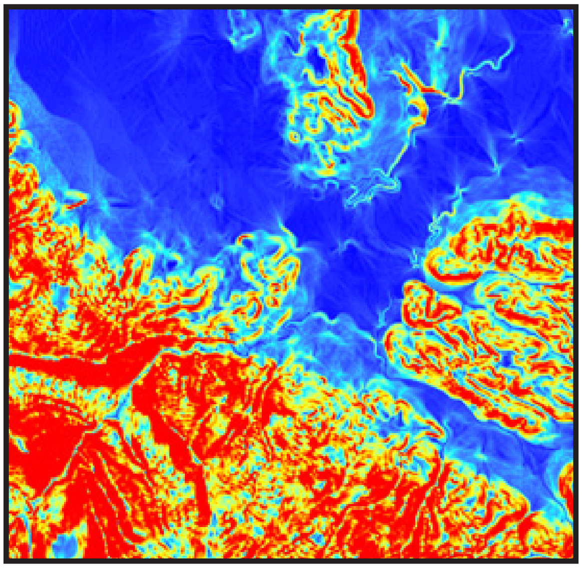
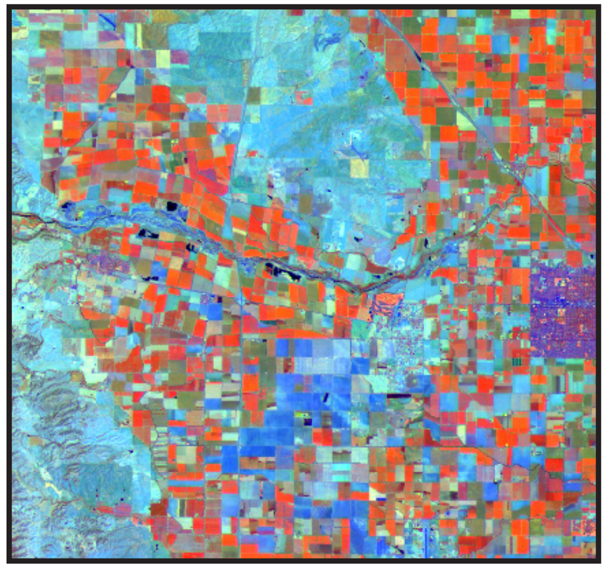
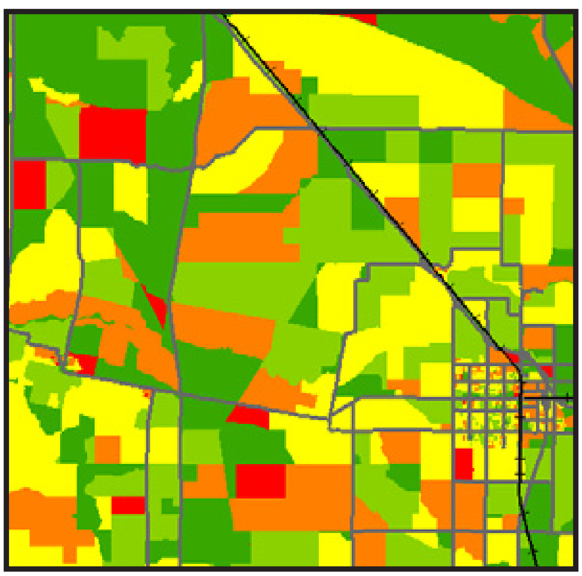
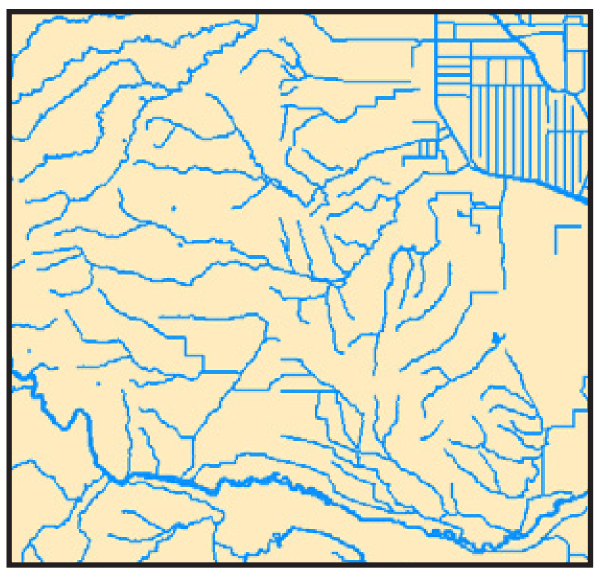
The Landscape Architecture Data Model

A Case Study in GIS Data Modeling









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LDA Senior Project - Spring 2009

University of California, Davis

The Landscape Architecture Data Model:
A Case Study in GIS Data Modeling

A Senior Project Presented to the faculty of the program of Landscape Architecture at the University of California, Davis in partial fulfillment of the requirements for the degree of Bachelors of Science of Landscape Architecture.

Presented by:
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at
University of California, Davis
on
the twelfth day of June, 2008

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Abstract

The primary objective of this project is to develop a geodatabase that can be used by undergraduate landscape architecture students in the site analysis phase of a design or planning project. As part of this process, useful datasets are discussed, and basic GIS concepts are explained. The spatial extent of the database covers Yolo County, and the relevant map scale for analysis and map production is 1:24,000 or less. The database consists entirely of publically available data that can be obtained online from a variety of sources. The organization of the database is also described and sample map products are displayed. Finally, a simple analysis is performed to demonstrate how the data can be used.

Table of Contents

Introduction

Background

The profession of Landscape Architecture addresses the "analysis, planning, design, management, and stewardship of the natural and built environments" (ASLA). Project sites can range from rural recreation areas to dense urban plazas. The broad scope of the profession therefore requires that a well-trained landscape architect is capable of understanding local site conditions, and can produce a responsive and appropriate design. This requires not only a thorough understanding of the issues involved, but also the ability to map and analyze the relevant variables, to capture their spatial distribution and variability. This is a challenging and time-consuming process, because it involves the collection of specialized data from a range of scientific disciplines, from soil scientists, to wildlife biologists, to sociologists. As a result, site analysis has not always received the attention that it deserves.

In recent years, however, the development of geographic information systems (GIS), along with the general availability of spatial data, has made it possible to conduct increasingly detailed and accurate analysis (LaGro 2008). Even students, working within the compressed timeframe and low budgets of an academic project, can now access and analyze significant quantities of spatial data. This, however, requires a basic proficiency for working with spatial data in a Geographic Information System.

Project Summary

The objective of this project is to examine some basic GIS concepts, and to develop a simple GIS database which can be utilized in the context of an undergraduate landscape architecture studio class. The first step in the project was to identify the required information products that would be useful to students of landscape architecture. The next step was to define the scope of the system in terms of how much data is needed and what would be required to implement the database. Next, publically available datasets were evaluated to determine if they could provide useful information for the desired information products. Finally, relevant datasets were acquired and organized within a GIS database. This database was implemented as an ESRI Geodatabase, which allows sophisticated spatial relationships to be modeled. The basic structure of the data model is described, including brief descriptions of the different datasets that are included. Before elaborating on the specifics of the project, some basic GIS concepts will be introduced.

Geographic Information Systems

Definition and General Concepts

A geographic information system is "an integrated collection of computer software and data used to view and manage information about geographic places, analyze spatial relationships, and model spatial processes. A GIS provides a framework for gathering and organizing spatial data and related information so that it can be displayed and analyzed" (ESRI 2006). In other words, a GIS is a database that stores spatial information. It allows people to interact with those data through maps and other tools.

The data in a GIS is referenced to a specific location on the planet. This is what allows GIS data to be instantly displayed in the correct location and overlaid with other data. Geographic locations are typically specified by either latitude and longitude values, or by coordinates in a map projection. Map projections allow real-world objects on the surface of the earth to be accurately represented on a map. They are necessary because the earth is a roughly spherical shape with an irregular surface, while maps are typically two-dimensional and flat. Map projections mathematically transform coordinates from their location on the three-dimensional Earth, to a two-dimensional map. This always involves some sort of compromise in the accuracy of representing areas, shapes, distances, and directions. It is impossible to simultaneously preserve all four of these properties when projecting a three-dimensional surface to a two-dimensional one (Lo and Yeung 2007). As a result, the choice of an appropriate map projection is an important decision when working with geographic information.

GIS data is typically represented in thematic layers. In other words, features are grouped into a layer with other similar features. All of the features in one layer must share the same set of attributes. These layers can then be combined and overlaid on top of each other in a map. Common thematic layers include vegetation, soils, land use, etc. In addition, different types of data are often best represented by a certain type of data model. The three basic ways to model data in a GIS are the vector format, the raster format, and the triangulated irregular network (TIN). Each representation has particular strengths and weaknesses in its ability to accurately represent real-world features (Zeiler 1999).

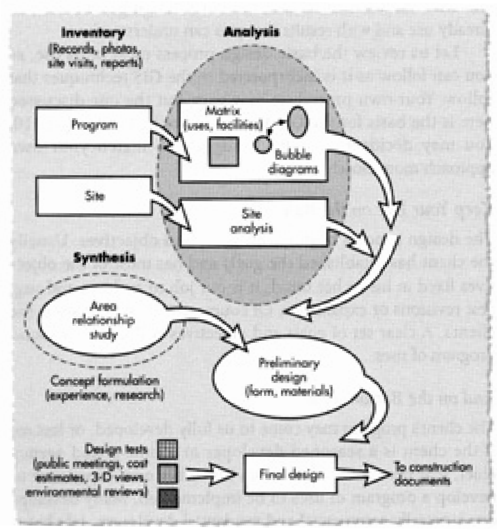
For landscape architects, GIS is most useful on large scale planning and design projects. The real strength of GIS is its ability to manage large quantities of spatial data, and to provide the tools for querying and analyzing data. Landscape architects, however, can use GIS at all scales to evaluate the suitability of locations, examine the feasibility of proposals, allocate uses within a site, and predict the impacts of different decisions. By making the data accessible, patterns and relationships can be better understood, and more intelligent land use decisions can be made.

Project Description

Information Products

The first step in the project was to define the required information products that the GIS database should provide. Information products are the final products or services that the intended users of the GIS will need. They may take the form of maps, reports, graphs, lists, or a combination of these things. Understanding the desired output from the beginning helps guide the design of the database and improves the likelihood of success. It also determines what datasets are needed as input.

The database is intended to meet the needs of undergraduate landscape architecture students at UC Davis who are interested in using GIS in their design studio classes. Its primary function would be to support the site analysis phase of a design or planning project. As a result, it should be able to provide relevant information on the physical, biological, and cultural features in the area of the project site. Preferably, experiential features would also be described.



The Design Process is often represented differenty, as shown by Figures 1 and 2.

Regardless of the representation, GIS typically plays its biggest role in the site inventory and analysis phases.

Figure 1 - Reproduced from Hanna and Culpepper 1998.

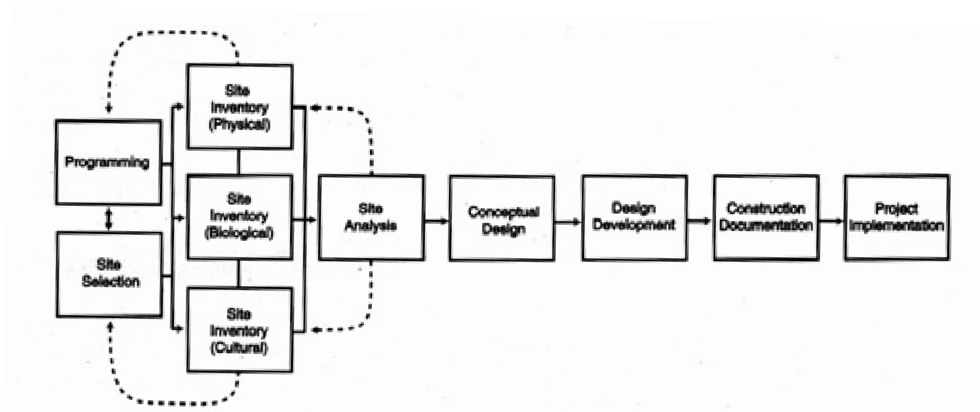


Figure 2 - Reproduced from LaGro 2008.

Often these variables will need to be evaluated on a project-by-project basis, but some, such as viewsheds, are able to be derived from existing GIS data.

Scope

The spatial extent of the database covers Yolo County, and the relevant map scale for analysis and map production is generally 1:24,000 or less. These criteria were determined based on the goals of the project, and on the limitations of certain datasets. This should be sufficient for most city or regional planning projects. One of the benefits of the geodatabase, however, is that the design schema can be easily modified and adapted to new situations. As a result, the geodatabase design produced during this project can be a useful starting point for many future applications within the domain of student landscape architecture projects.

Geodatabases

A geographic data model is an abstract digital representation of real-world features. It provides the framework that allows spatial information to be accurately represented and analyzed. Geographic data models can be implemented in a variety of different ways, with varying levels of sophistication and complexity. The data model described in this project was implemented on the ESRI Geodatabase.

The ESRI Geodatabase allows for the relatively sophisticated representation of spatial data. It allows specific rules and relationships to be defined, which can improve the internal consistency of the data and represent real-world features more accurately. It also allows advanced spatial relationships such as topology and geometric networks to be modeled (Arctur and Zeiler 2004). In addition, the geodatabase provides a single, centralized location for the storage of spatial data.

There are many types of complex relationships that can be modeled in a geodatabase. Topology rules, for example, ensure the integrity of the spatial relationships between features. An example of a topology rule is that state polygons must not overlap. Relationship classes define general associations between features. For example, the association between a parcel of land and its owner could be represented by a relationship class. The original goal of this project was to produce a fully developed data model that defined topology rules, relationships between associated feature classes, and specific validation rules. Due to time limitations, many of these more advanced features were not developed. Designing a geodatabase, however, is an iterative process, which should be refined and developed over time (Tomlinson 2007). The result of this project represents the first step in that process. Many sources of useful data were identified and logically organized within a geodatabase. The limitations of the data have been evaluated and future goals and improvements have been identified.

Geodatabase Description

General Description and Organization

All of the data collected for this project has been organized within an ESRI File Geodatabase. The individual files have been clipped to the shape of Yolo County and projected into the California State Plane Coordinate System, Zone 2 (FIPS zone 0402). This zone uses the Lambert Conformal Conic Projection and the North American Datum of 1983. US Survey feet are the linear unit of measurement. This coordinate system was selected because it is used by the local county and municipal governments, and because of the low amount of distortion that it causes.

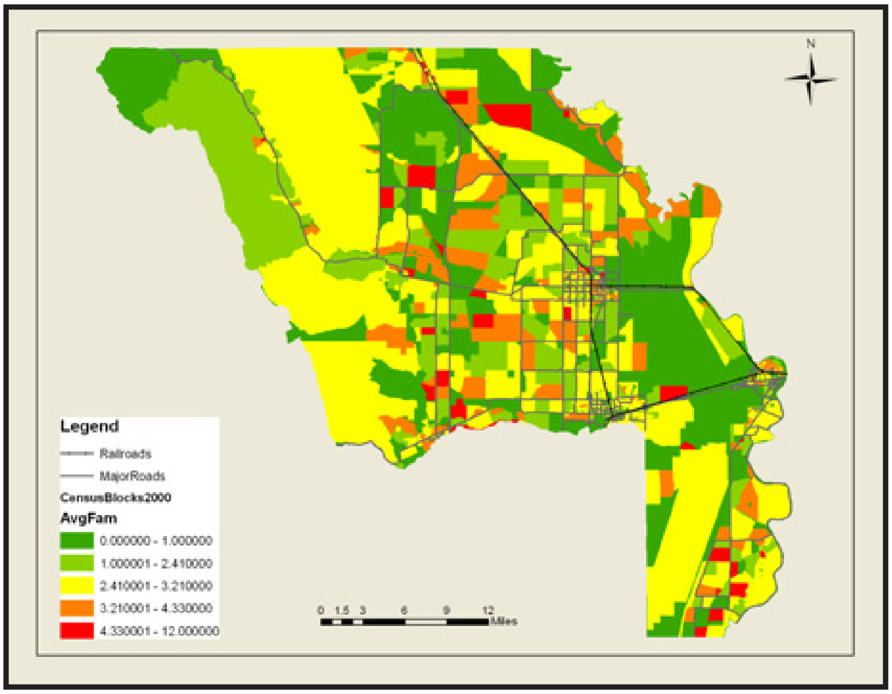
Within the geodatabase, feature classes are grouped thematically into feature datasets. The categories for the feature datasets are: political boundaries, census data, farmland and soils, hydrology, land use, and transportation. Several standalone raster datasets are also included. They are: USGS Digital Raster Graphics, a digital elevation model, a Landsat image, and a land cover raster. Hillshade and slope layers were also derived from the digital elevation model. All initial raster datasets have been merged into a single raster dataset and clipped to the boundaries of Yolo County. This was done to improve display performance and remove seams in the data.

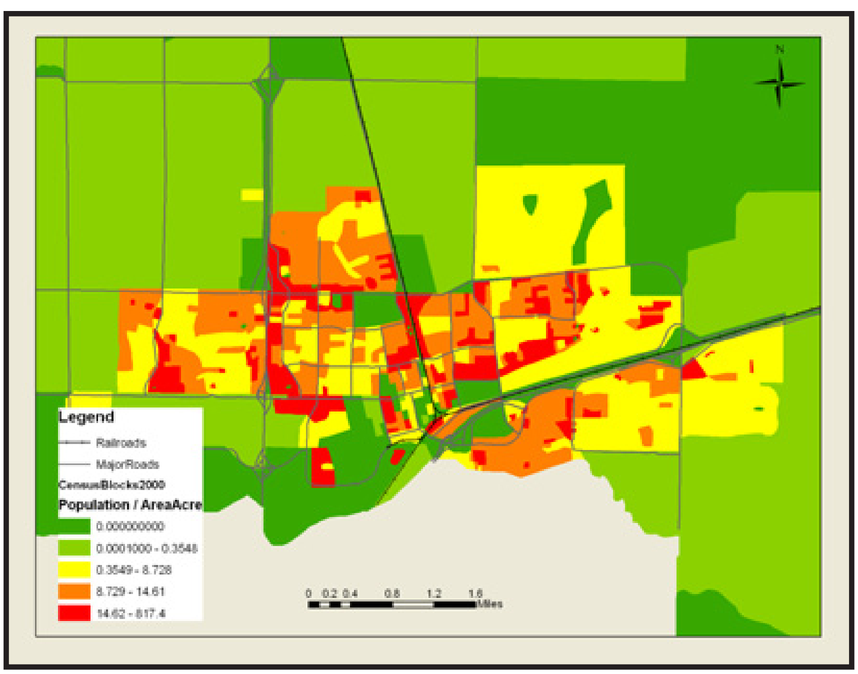
Thematic Layers

The following are brief descriptions of the different thematic layers that are represented in the geodatabase, along with sample images of some of the layers:

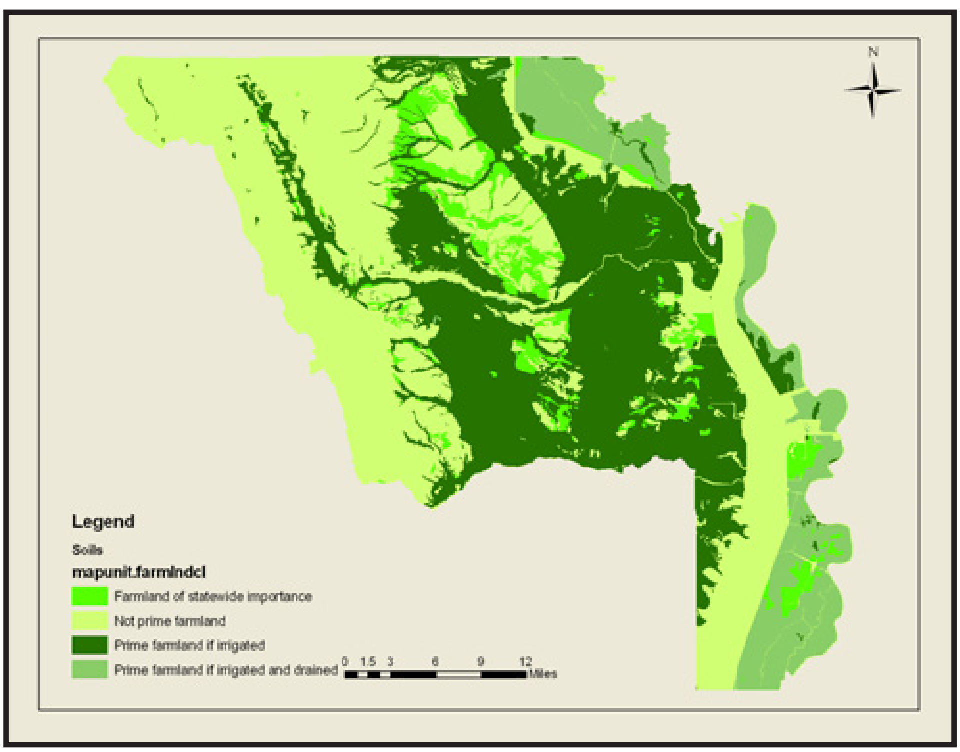
- Political Boundaries
    - Cities – City limits for all incorporated cities in Yolo County. Originally from Census TIGER files, now updated by Yolo County and SACOG staff. Attributes include city names and areas (polygons)
    - UC Davis –UC Davis boundary (polygon)
    - Yolo County – Yolo County Boundary (polygon)

- Census
    - 2000 Census Blocks – Census blocks from the year 2000 census. The census block is the smallest unit of aggregation that the census department releases public data for. Additional data such as population counts have been appended to this layer (polygons)

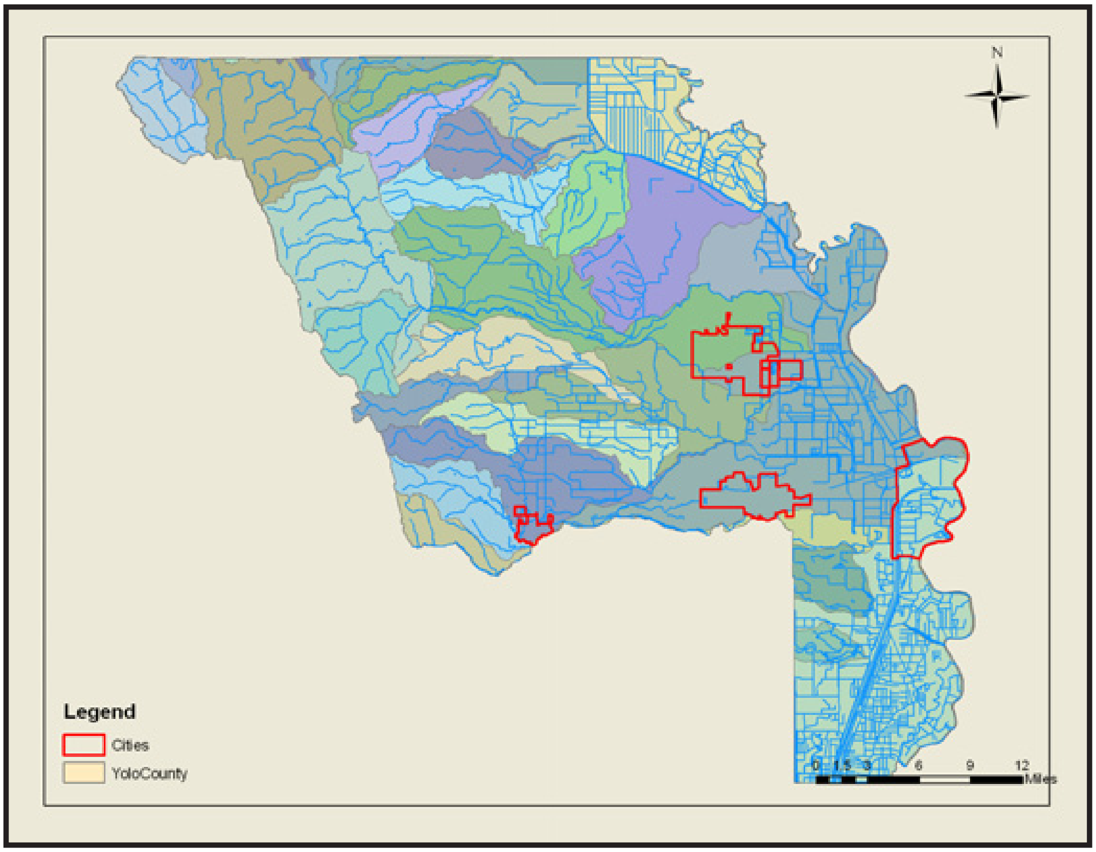




- Farmland and Soils
    - Regional Farmland – Created by CA Department of Conservation, Farmland Mapping Program. Attributes include type and importance (polygons)
    - Soil Point Features – Significant point features associated with the soil. From the NRCS Soil Survey Geographic (SSURGO) Database (points)
    - Soil polygons – Soil data from the NRCS Soil Survey Geographic (SSURGO) Database. There is a huge amount of data associated with this dataset. Only a small amount has been included with the database for this project, but essentially all of the information in the soil survey can be linked to the soil polygons and mapped (polygons)
    - Williamson Act – Shows the current status of Williamson Act contract, including farmland status. Maintained by the California Department of Conservation (polygons)



- Hydrology
  - USGS Digital Line Graphs, lines – Detailed hydrologic features including streams, and drainage channels. Derived from USGS topographic maps (lines)
  - USGS Digital Line Graphs, polygons – Same, but showing polygon features such as lakes and wide channels (polygons)
  - Groundwater Basins - Groundwater basins as defined by the California Department of Water Resources. Designated based on geological and hydrological conditions.
  - Watersheds – Watershed Boundary Dataset derived from USGS DRG's (polygons)
  - Hydrologic point features – Point features from the USGS Digital Line Graphs. (points)
  - Levees – Source is from NRCS Soil Survey Geographic (SSURGO) Database (lines)
  - Rivers and Streams - major hydrologic features digitized from 1:24,000-scale USGS topographic maps (lines)
  - Vernal Pools – Vernal pool complexes more than 40 acres in size. Attributes include density rating (polygons)
  - Wetlands – From U.S. Fish and Wildlife Service National Wetlands Inventory – Attributes include wetland type and area (polygons)
  - Yolo Bypass – Yolo Bypass from SACOG (polygon)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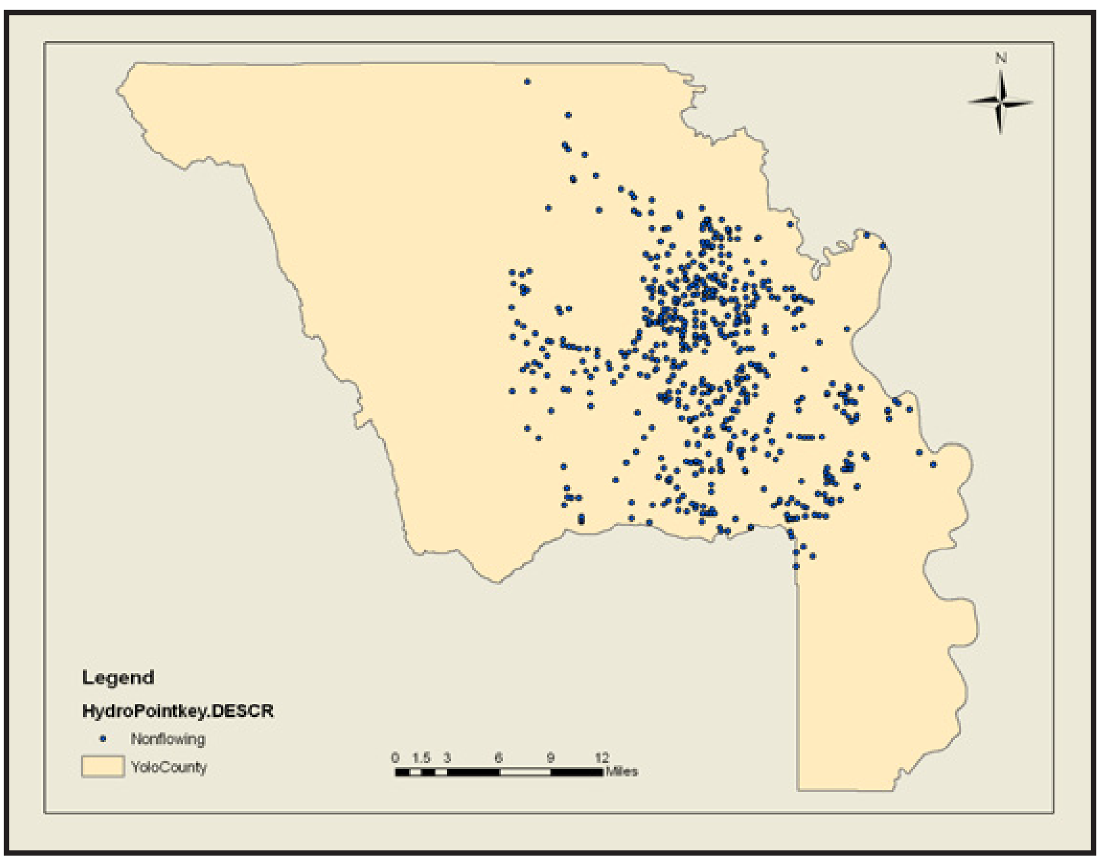
Legend
Cities
YoloCounty
0 1.5 3 6 9 12
Miles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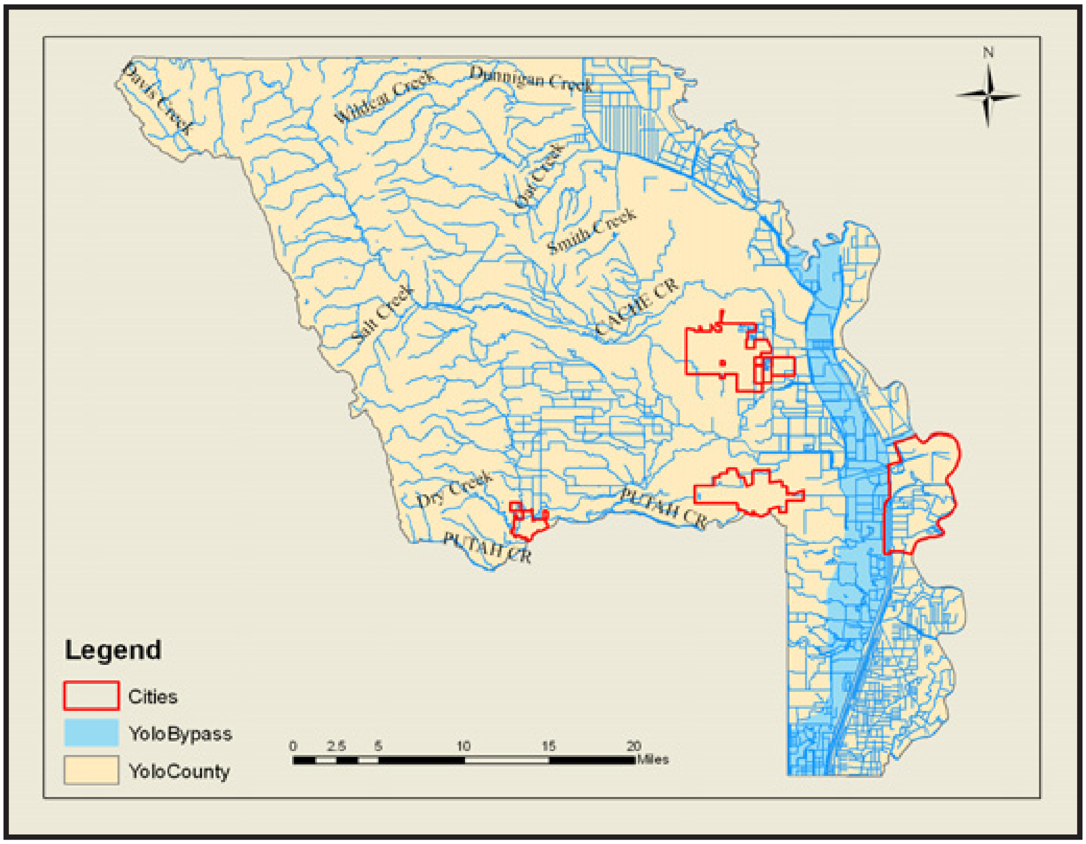
YoloCounty
0 1.5 3 6 9 12
Miles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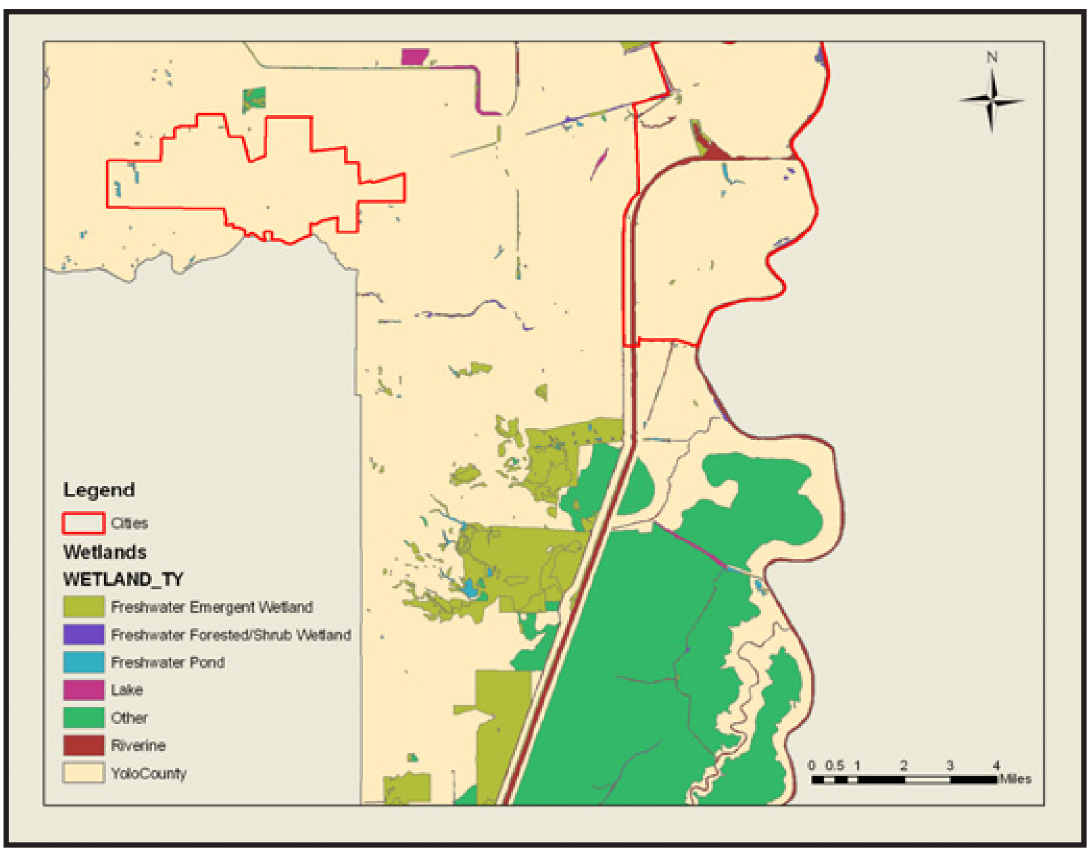
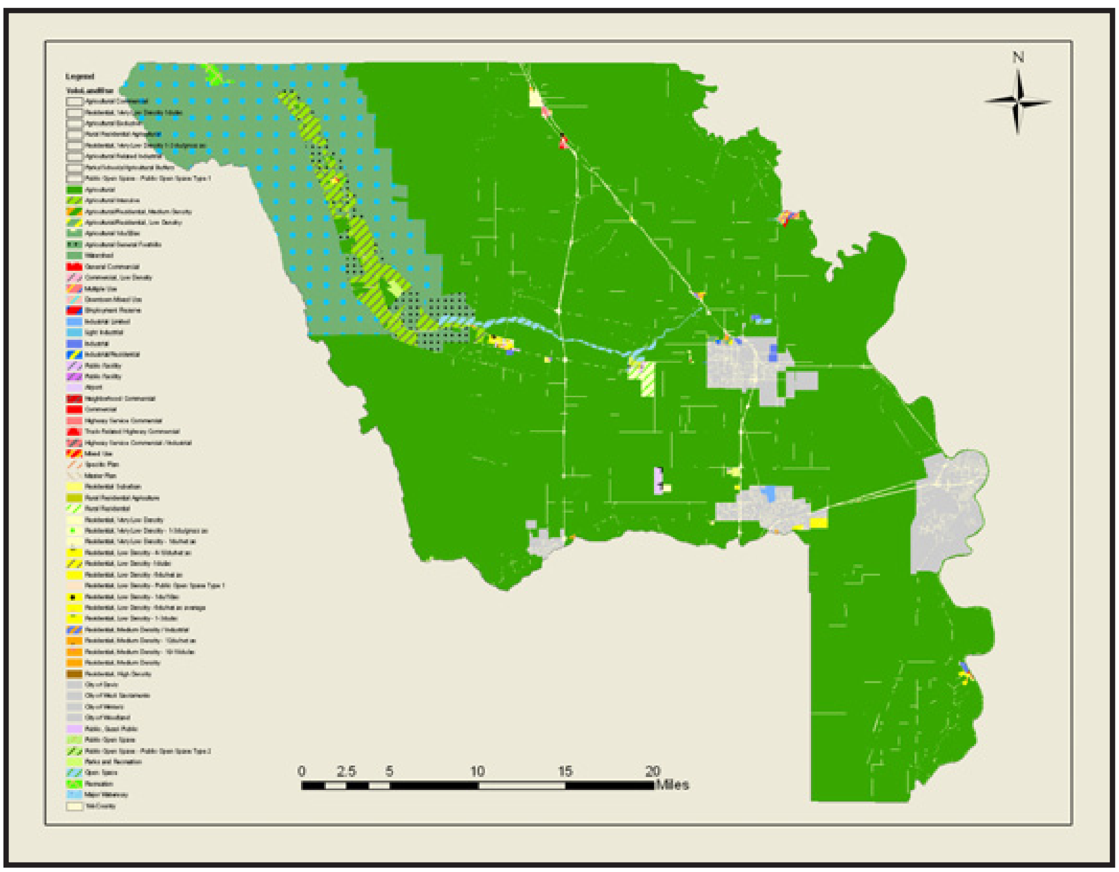
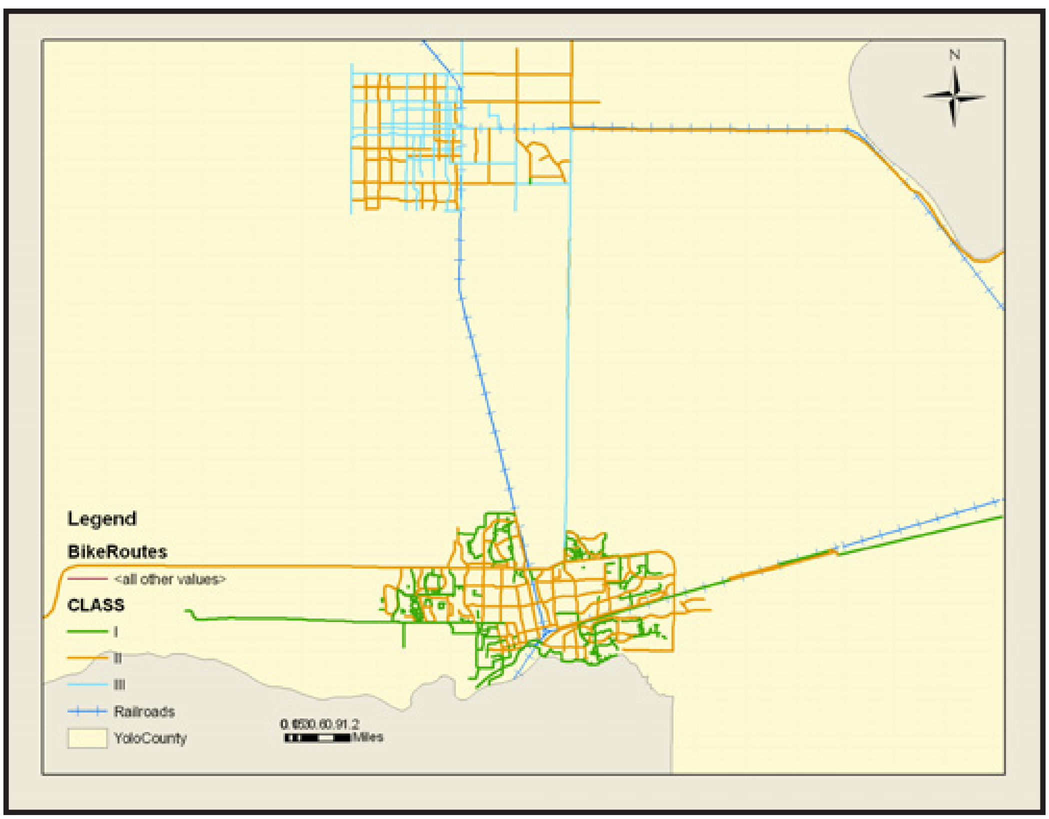
Davis Creek
Wildcat Creek
Dunnigan Creek
Oat Creek
Smith Creek
Salt Creek
CACHE CR
Dry Creek
PUTAH CR
PUTAH CR
Legend
Cities
YoloBypass
YoloCounty
0 2.5 5 10 15 20
Miles

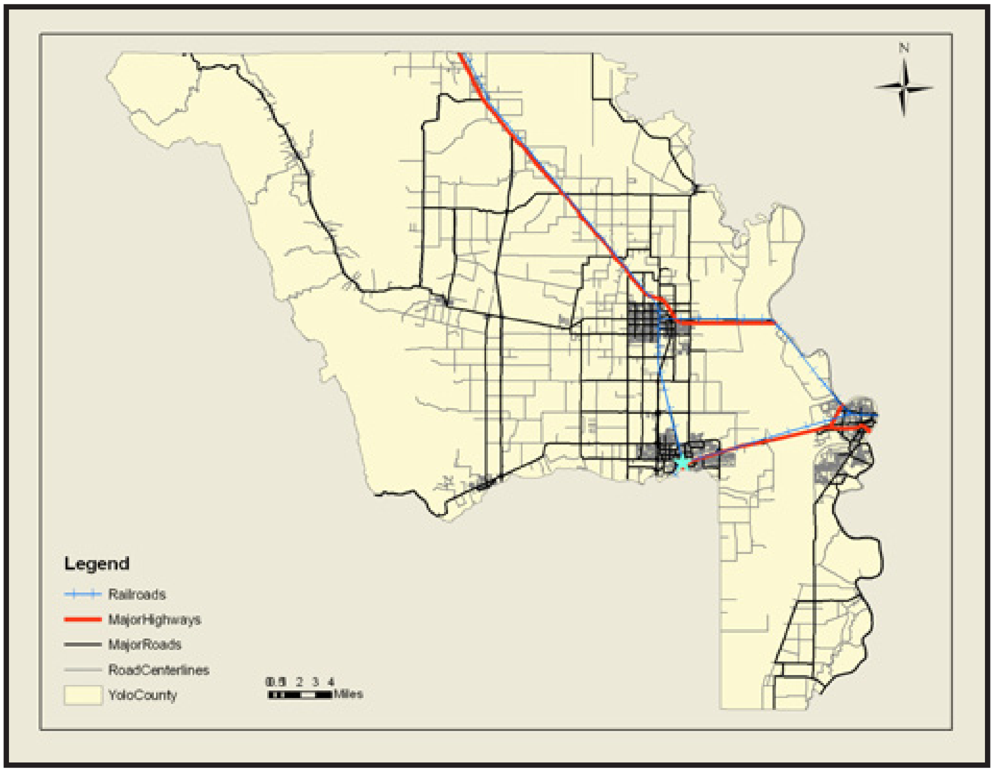

N
Legend
Cities
Wetlands
WETLAND_TY
Freshwater Emergent Wetland
Freshwater Forested/Shrub Wetland
Freshwater Pond
Lake
Other
Riverine
YoloCounty
0 0.5 1 2 3 4
Miles

- Land Use
  - Parks – Parks in Yolo County, from SACOG (polygons)
  - Tax Parcels – Parcels from County of Yolo. Attributes include street addresses (polygons)
  - Yolo County Land Use – Land Use for unincorporated areas of Yolo County. City-level land use is also available, but is not included in this database. Attributed include land uses and planning areas (polygons)
  - Yolo County Zoning – Same as land use, but for zoning (polygons)



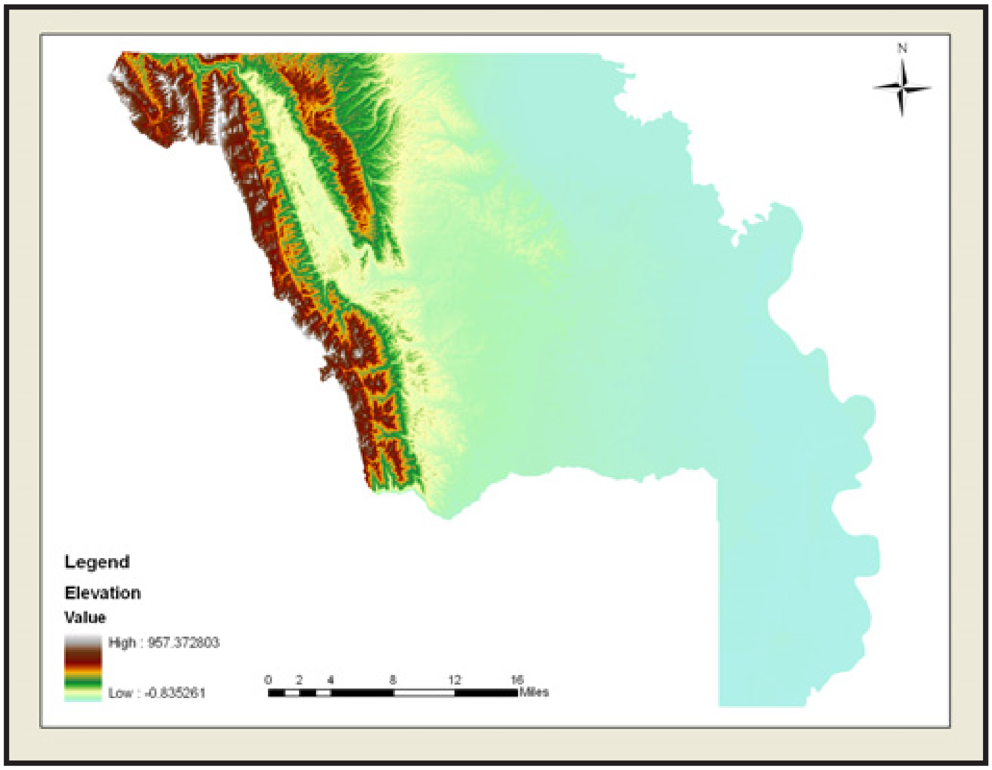
- Transportation
  - Amtrak Stations – The station in Davis is the only one in Yolo County (point)
  - Bike Routes – Bike Routes from SACOG. Attributes include status and class (lines)
  - Major Highways – Major Highways in Yolo County Attributes include lengths and names (lines)
  - Major Roads – Major roads in Yolo County. Attributes include road classes and number of lanes (lines)
  - Railroads – Railroads in Yolo County. Attributes include name of owner (lines)
  - Road Centerlines – Road centerlines for all of Yolo County. Attributes include street names and address ranges (lines)





Rasters:

- USGS Digital Raster Graphics – Scanned copies of USGS 7.5-minute topographic maps. A colormap is applied to ensure a consistent display (raster)
- Digital Elevation Model (DEM) – Extracted from the USGS National Elevation dataset. Merged into single seamless raster. Resolution is 1 arc-second (about 30 meters) (continuous raster)
- Hillshade – Derived from the DEM (continuous raster)
- Slope – Also derived from the DEM (continuous raster)
- Landsat image – Landsat 5 TM image acquired on June 8, 2009 (multispectral raster)
- Land Cover – Land cover and vegetation from the fire and resource assessment program. Attributes include Wildlife-Habitat Relationship (WHR) types and life forms (discrete raster)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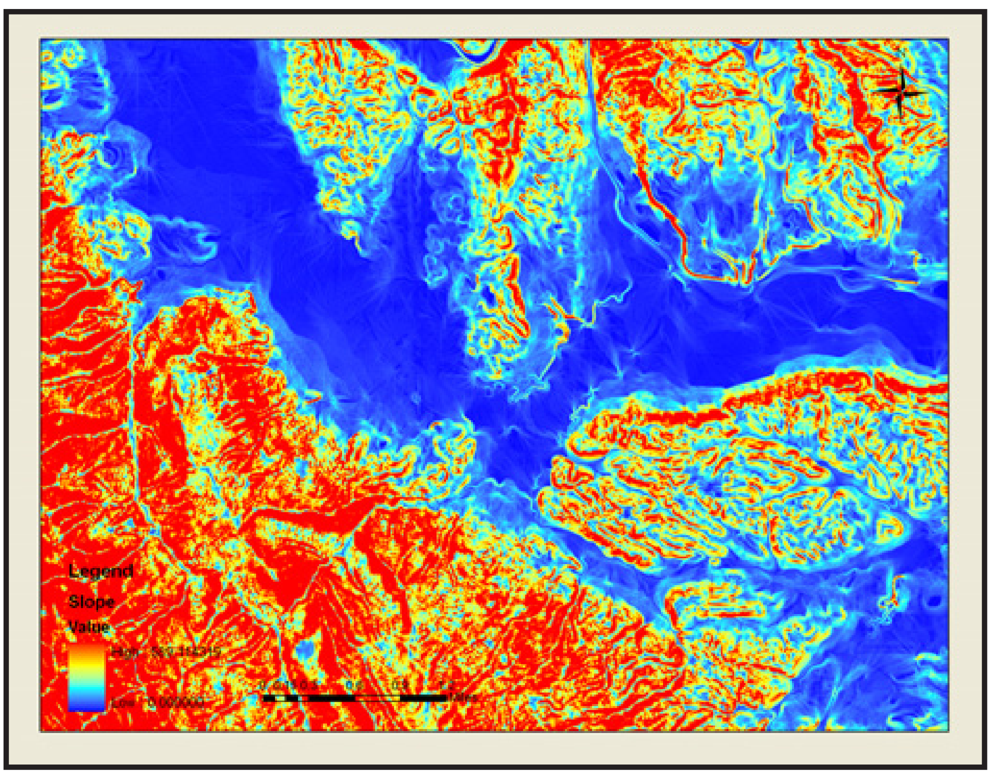
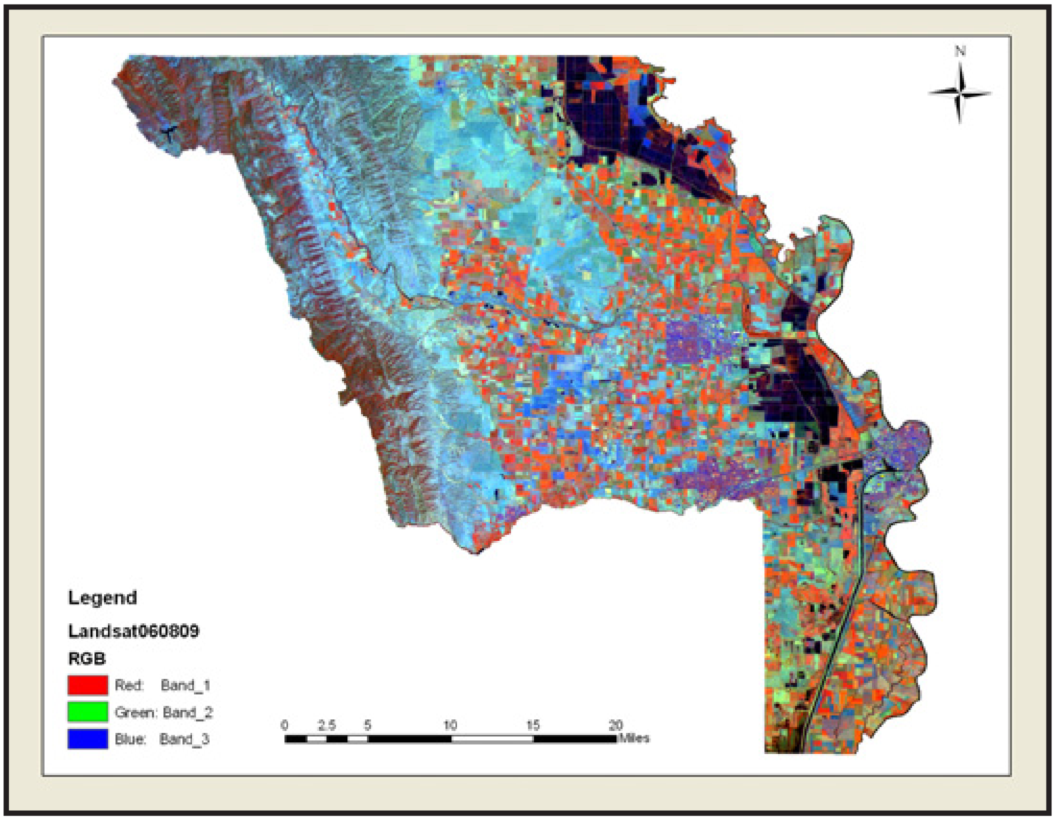
Legend
Elevation
Value
High : 957.372803
Low : -0.835261
0 2 4 8 12 16
Miles


Legend
Slope
Value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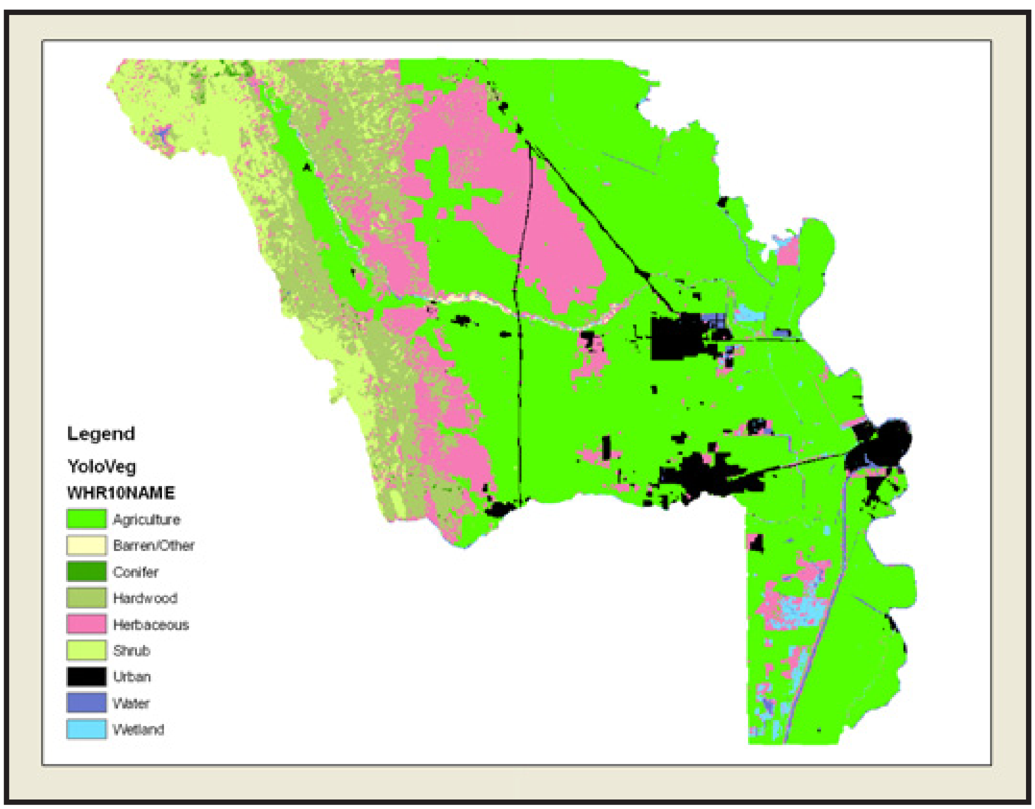
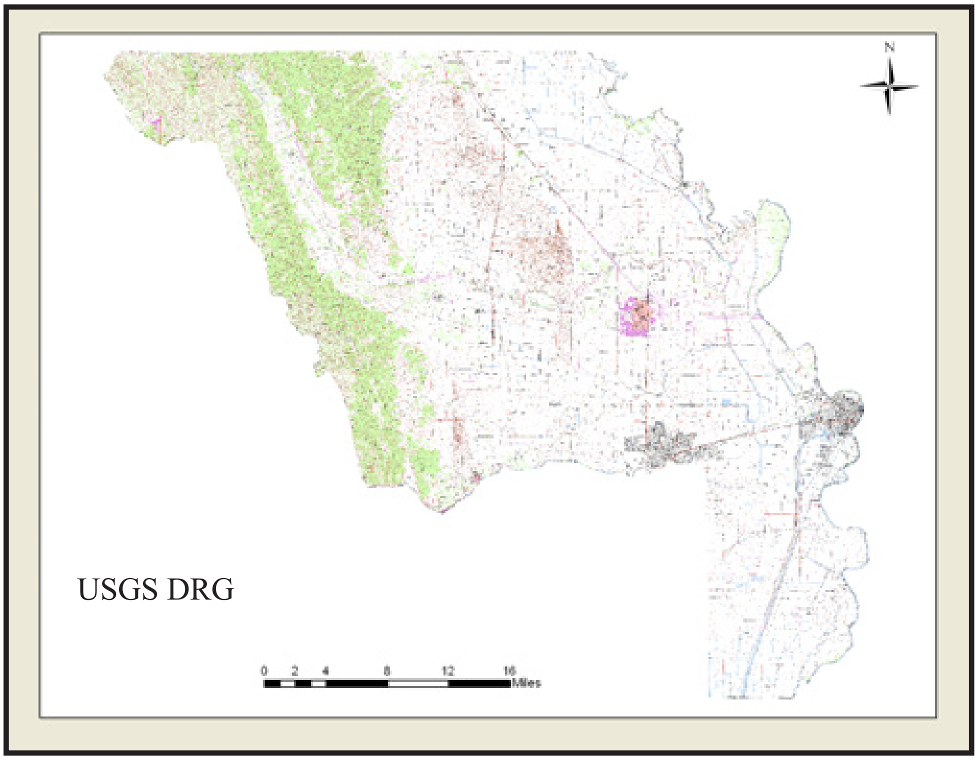
Legend
Landsat060809
RGB
Red: Band_1
Green: Band_2
Blue: Band_3
0 2.5 5 10 15 20
Miles


Legend
YoloVeg
WHR10NAME
Agriculture
Barren/Other
Conifer
Hardwood
Herbaceous
Shrub
Urban
Water
Wetland



Stand Alone Tables:

- There are also several stand alone tables that provide additional information for certain datasets.

Sources of GIS Data

Online sources

The amount and the quality of the GIS data that is available to the general public is rapidly increasing, and much of it is now available online. In addition, many nonspatial datasets can be associated with a geographic location through coordinates, or address information. The following are just a few of the many sources of GIS Data:

- City of Davis - http://cityofdavis.org/gis/index.cfm
- City of West Sacramento - http://www.cityofwestsacramento.org/services/gis/default.asp
- Yolo County - http://www.yolocounty.org/Index.aspx?page=587
- Sacramento Area Council of Governments (SACOG) - http://www.sacog.org/mapping/
- California Spatial Information Library (CaSIL) - http://casil.ucdavis.edu/casil/

Many additional sources can be easily found online through search engines or lists maintained by other organizations:

- UC Davis Library - http://www.lib.ucdavis.edu/dept/govinfo/mapcollection/gis.php
- Stanford University Library - http://www-sul.stanford.edu/depts/gis/web.html

In many cases, however, appropriate GIS data may not already be available for a site. This can often occur with small sites, where much more detailed data is required. In these cases, it is often necessary to create a new dataset from scratch. One easy ways of doing this is to trace features from an image, such as an aerial photograph. Another option is to collect field data using a GPS receiver.

GPS

The use of GPS is becoming increasingly frequent among both the scientific community and the general public. Collecting accurate information for use in a GIS, however, requires a basic understanding of how the technology works, and what its limitations are. GPS stands for the global positioning system, which consists of at least 24 operational satellites at all times, along with ground control and tracking stations. The satellites continuously transmit a microwave radio signal, which is composed of two carrier frequencies, two or more digital codes, and a navigation message. GPS receivers can observe this information and triangulate a position based on the calculated distances to each satellite (El-Rabbany 2006). Several different techniques have been developed to improve the accuracy of these calculations. Different GPS receivers also have varying capabilities for making use of the different GPS observables.

One of the most important techniques for improving the accuracy of GPS measurements is called differential (or relative) positioning. This technique uses two GPS receivers, which simultaneously track the same satellites. The location of one of the receivers (the base receiver) is known very precisely, which allows the amount of measurement error to be determined. This error can then be corrected for in the other receiver, which is measuring unknown positions. Differential positioning allows measurements to be made on an accuracy level of a few meters to millimeters, depending on the quality of the receivers used. This is generally the accuracy required for most GIS applications.

The operation of a highly precise base receiver, however, can be a complicated and expensive operation. Fortunately, several different organizations operate permanent GPS reference station networks which provide correction data, often free of charge. One widely available source of correction data is provided by the U.S. Federal Aviation Administration (FAA). The system is known as the wide area augmentation system (WAAS). It consists of 25 reference stations, two master stations, and two geostationary satellites. Measurements taken at the reference stations are used to estimate the differential corrections, which are then transmitted to GPS receivers across the country via the geostationary satellites (El-Rabbany 2006).

Students in the landscape architecture program have access to GPS receivers from the Center for Regional Change, which use the WAAS to take measurements at an accuracy level of about 2-5 meters. This is typically sufficient for collecting spatial data that is going to be used in a GIS.

Remote Sensing

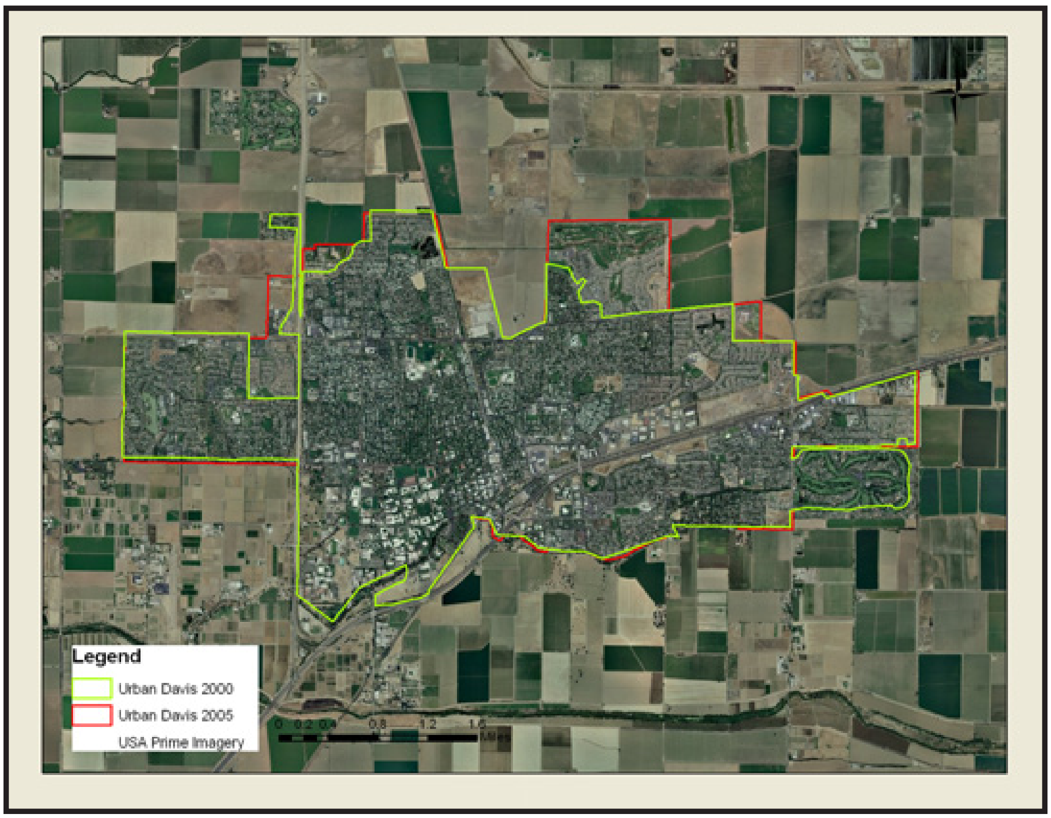
Remote sensing data are another very useful source of spatial information. Remote sensing is a very diverse field, which makes it somewhat difficult to define. In general, however, remotely sensed data is acquired by a sensor located on an aerial or a satellite platform.
By measuring variables such as the spectrum of reflected light, or the amount of energy backscattered from a surface, it is possible to determine certain things about the properties of that object.

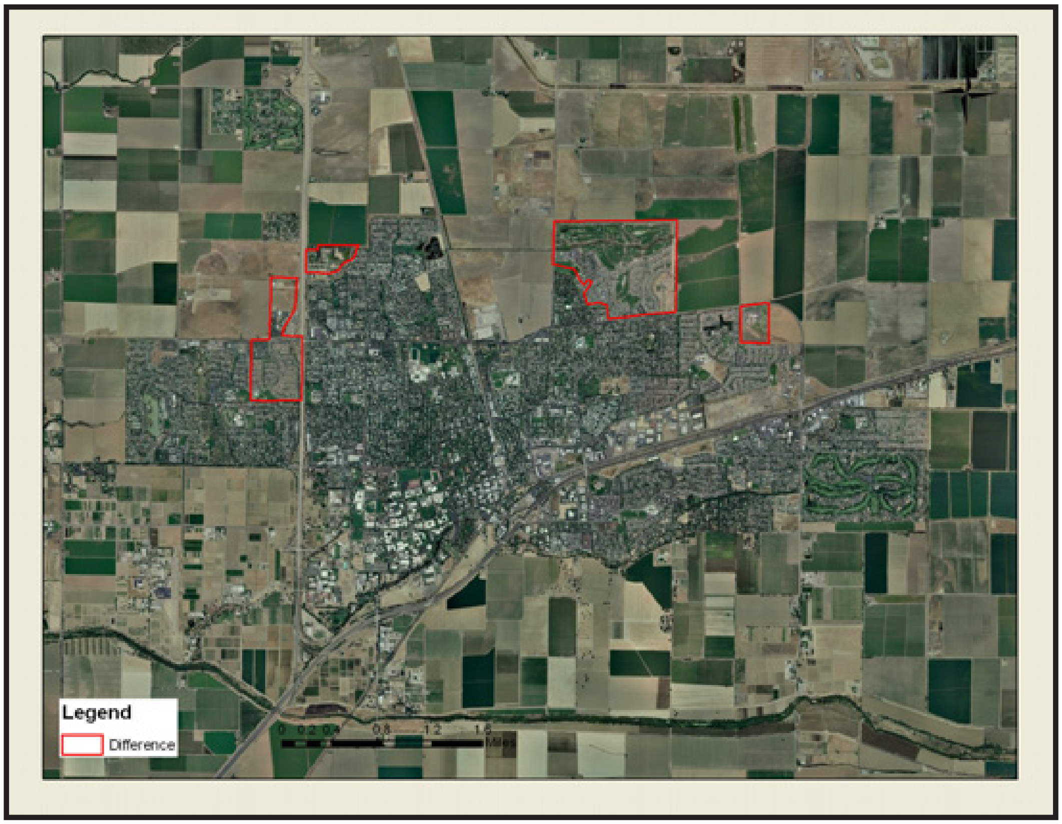
Remotely sensed data can be used to map biophysical variables such as biomass, elevation, and soil moisture. By combining various biophysical variables, it is also possible to map hybrid variables such as land use, land cover, and vegetation stress. Remote sensing has many limitations, but it is capable of providing large quantities of useful spatial information quickly, and at a relatively low cost (Jensen 2007). Satellite-based sensors, for example, can monitor the earth almost continuously. This allows data to be archived and compared over long periods of time.

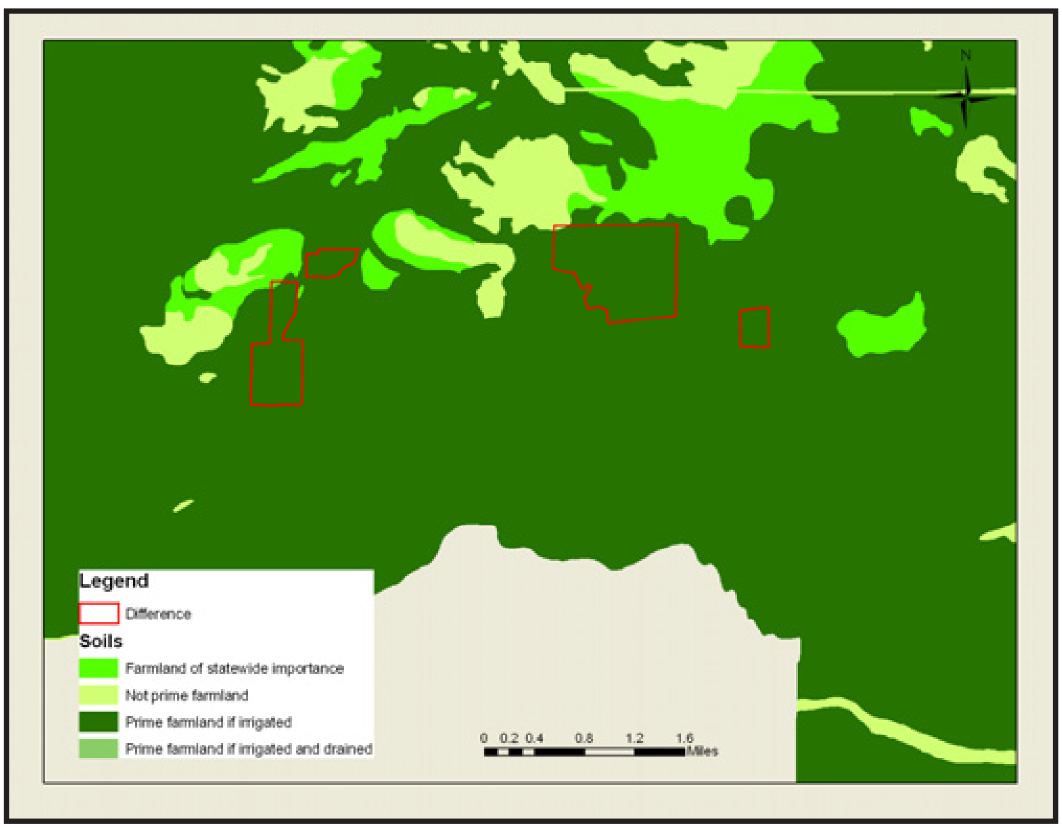
The database developed for this project includes Landsat imagery covering all of Yolo County. The Landsat Program is managed by NASA and the USGS, and has been collecting satellite imagery since 1972. There are currently two Landsat satellites in orbit, Landsat 5 and Landsat 7 (Landsat 6 failed to reach orbit). Most of the data is available online and can be downloaded free of charge. This makes it an excellent resource for both current and historical imagery. Between the two active satellites, new imagery is acquired for an area every 8 days.

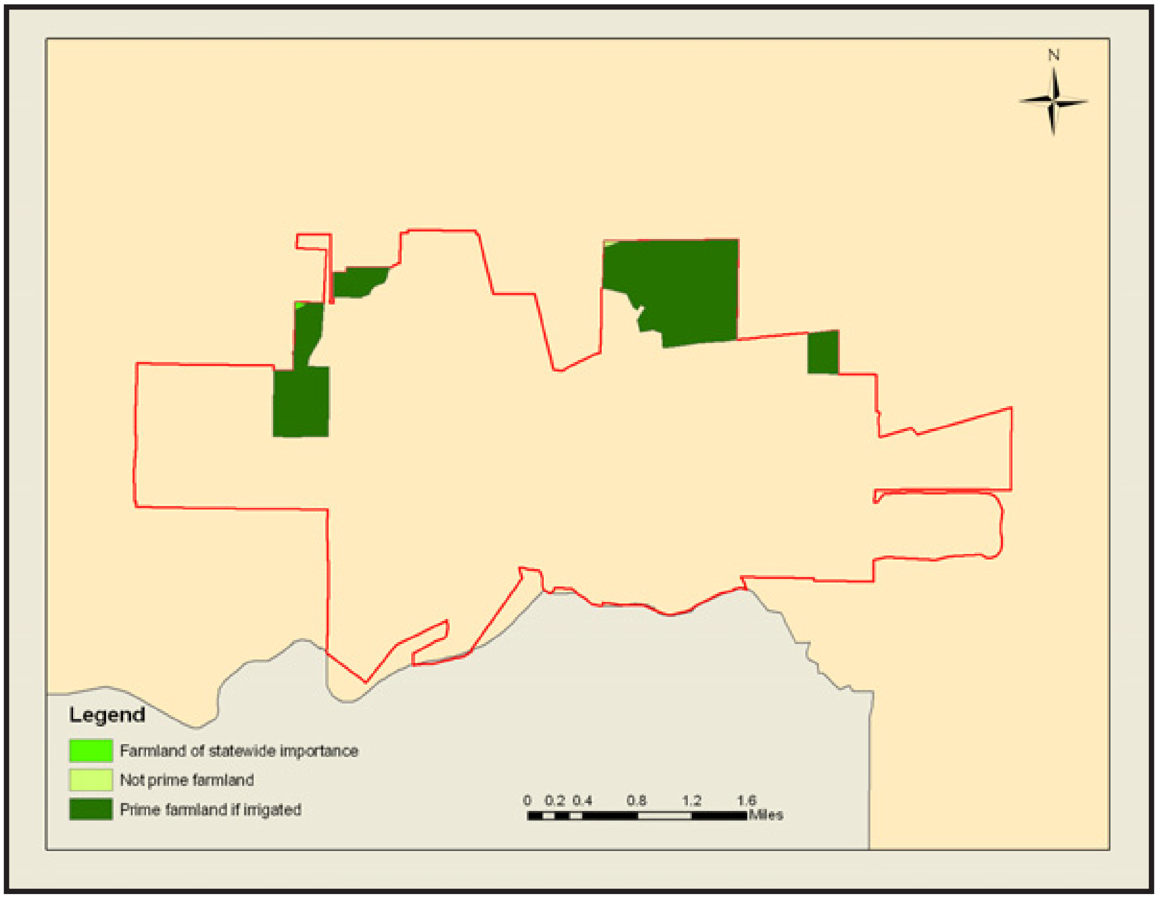
Case Study

This project does not focus on methods of data analysis, but the following example demonstrates a very simple way that GIS data can be used. Loss of prime farmland from urban expansion is a serious concern, particularly in the Central Valley. By comparing datasets from different periods of time, it is possible to determine how much change has occurred. In the following graphics, urban areas from the 2000 census are compared to the current city boundaries. Areas of significant change are identified and verified with recent aerial photos. These areas are then intersected with soil data to determine how much prime farmland was lost.




Legend
Difference
0 0.2 0.4 0.8 1.2 1.6
Miles


N
Legend
Difference
Soils
Farmland of statewide importance
Not prime farmland
Prime farmland if irrigated
Prime farmland if irrigated and drained
0 0.2 0.4 0.8 1.2 1.6
Miles



Total Area of Farmland Lost:
- Statewide significance - 1.75 acres
- Not prime farmland - 1.89 acres
- Prime if irrigated - 675.47 acres

Conclusion

This example, while relatively simple, illustrates the power of a GIS database to integrate spatial data from several different sources in order to answer a question. The database developed in this project takes the first steps towards the development of a more sophisticated Landscape Architecture Data Model.

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