Runoff potential changes due to increased urban development in Denton County, Texas

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Introduction

Increased urbanization in Denton County could affect rates of runoff potential, which could eventually affect the quantity of the county's water – if it has not already. The construction of new parking lots, sidewalks, and many new homes and buildings create impervious surfaces that normally increase storm runoff volumes and peak discharges (Guay 1996). Urban runoff is the water that flows off lawns, streets, paved areas, and rooftops during and after a rainstorm. A problem with a rapid increase in urbanization (many new homes and buildings) is that water runoff volumes for newly developed lawns are significantly greater than runoff from older lawns (Legg et al., 1995). This could be harmful to our water supply because Denton County's population is growing very rapidly.

Our group would like to find out if the runoff potential from the data of 1999 in Denton County is greater than it used to be in 1988 because of urban development. Denton County encompasses 957.7 square miles in north central Texas, and is centered at 33.2043 N and 97.1176 W. It has experienced rapid growth in the last several decades. The Census Bureau reports a population of 273,525 for the county in 1990, with 74% living in urban areas. Estimates for 1999 show a nearly 50% increase, up to 404,074. The North Central Texas Council of Governments (NCTCOG) predicts the population to reach 784,700 by the year 2025;

this amounts to a 186% increase over 1990 levels. Such tremendous growth in the population will naturally bring with it explosive urban development, much of it within the flood plains of major waterways such as the Elm Fork of the Trinity River. Urban development generally decreases stormwater infiltration and increases runoff, which in turn increases the likelihood and potential severity of flood events. Because floods can be devastating in terms of loss of life and property, Denton County was targeted as an appropriate region in which to study the increase in runoff potential as a result of development.

We will use a model to determine changes in runoff potential between 1988 and 1999 land-use images. With higher runoff potential, less water infiltrates into the ground. This could affect our water quantity availability as our population in Denton County increases. We are interested in that fact that if land-use changes, due to urban development and rural land-use changes, has changed our runoff potential as well. Some examples are conversions of farmland and grassland prairies to big technological business buildings, and parking lots. Our hypothesis for this project is that runoff potential has increased in Denton County from 1988 to 1999 due to land-use changes.

Literature Review

Urban runoff: There have been storm-runoff characteristic studies done on Perris Valley, California; Madison, Wisconsin; Long Island, New York; Ramsey County, Minnesota; Baltimore, Maryland; Salt Lake City, Utah and Austin, Texas. We have government journals and assessments on all of these cities about urban runoff and the characteristics thereof to help us assess our information from Denton County. The books “Effects of increased urbanization from 1970’s to 1990’s on storm runoff characteristics in Perrris Valley, California was written by Guay in 1996. “Effect of urban stormwater runoff on ground water beneath recharge basins on

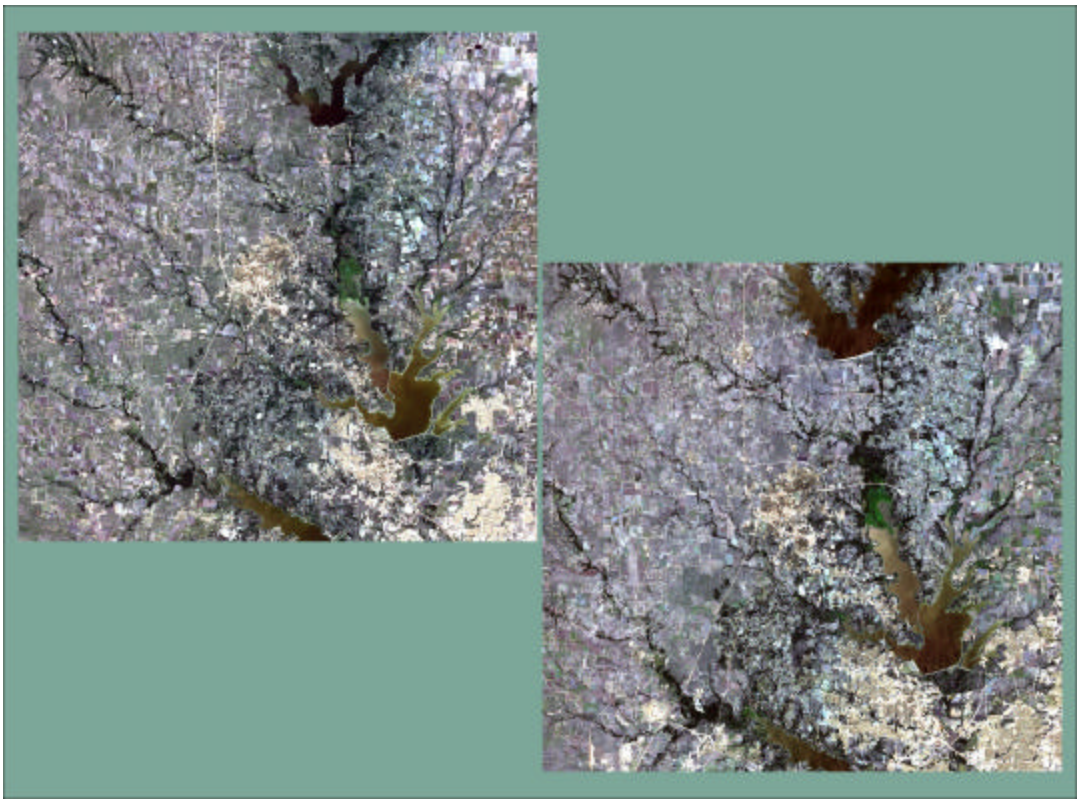
Long Island, New York" was by Ku and Simmons and was written in 1995. We have five other references for the other cities listed in the literature cited.

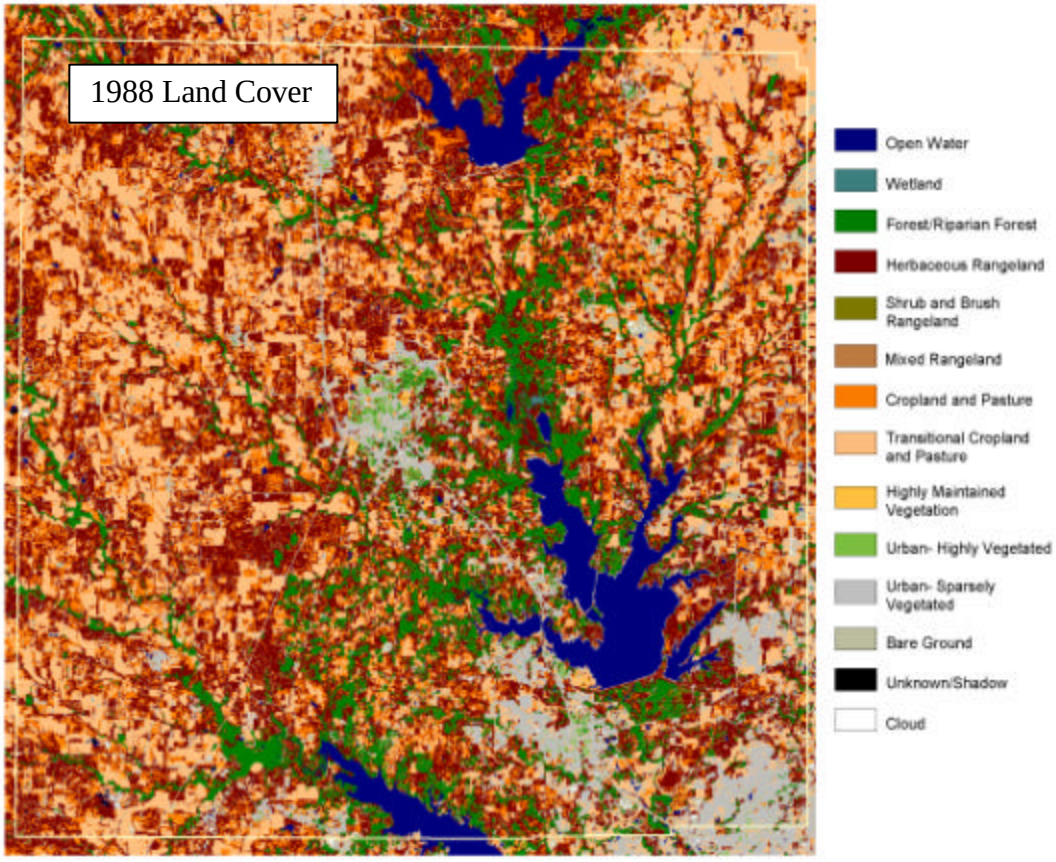
Increased urbanization – There is a great resource about effects of urbanization from the 1970's to the 1990's in Perris Valley, California (title is above and in literature cited) that helps us compare Denton County to another growing city. Statistics can be found from city government offices and census data.

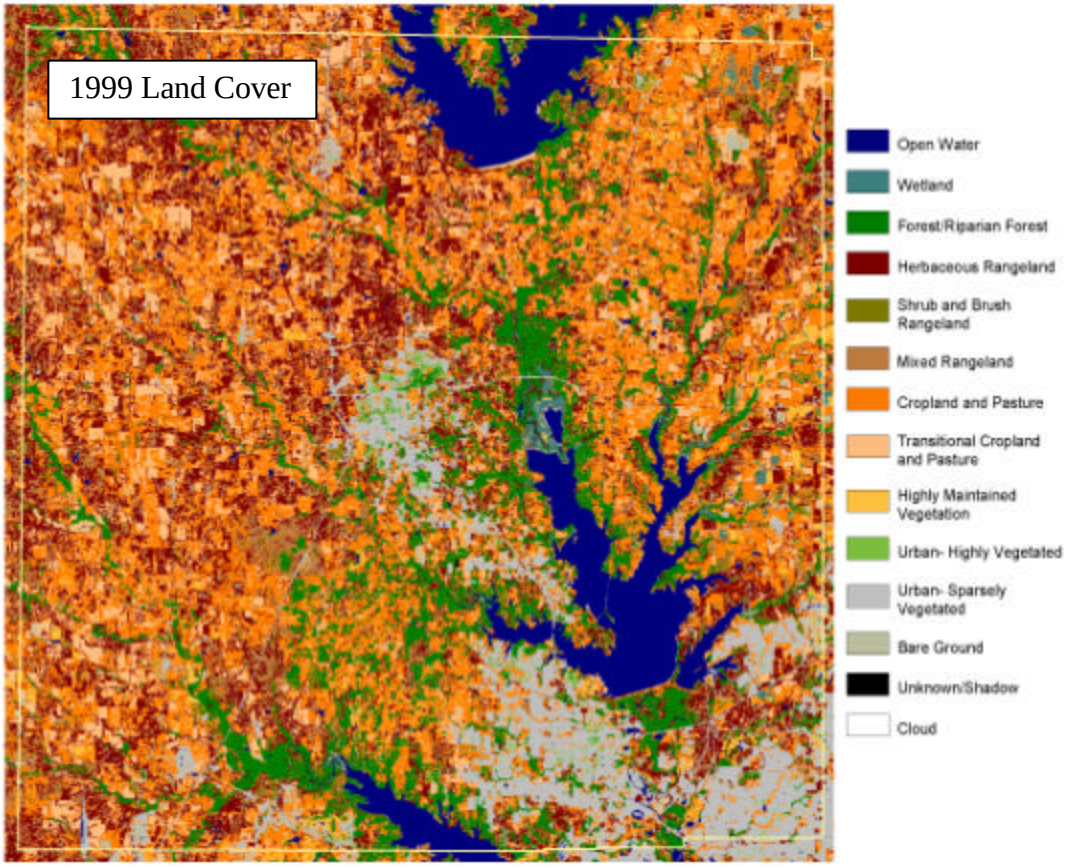
Porous pavements for urban runoff control – A good resource was a book written in the 70's from the EPA, called "Investigation of porous pavements for urban runoff control", but new resources need to be found through other facilities to obtain more recent data and helpful information on porous pavements. This resource will be sufficient to understand basic geologic processes about porous surfaces. Statistics on rainfall in Denton County can be obtained from any resource, and even from the Internet or the National Weather Service.

Methods

The study area for this project was Denton County, Texas. This study required five data layers, three of which involved land-use. Landsat 5 Thematic Mapper satellite images for 1988 (Figure 1) and 1999 (Figure 2) were obtained from the US Geological Survey (USGS) EROS Data Center. The raw images were reclassified and rectified using Texas Department of Transportation 1:100,000 road maps. Resolution for the layers was 30m x 30m pixel size. A display with land-use images from 1988 and one from 1999 were created in ArcView. Both 1988 and 1999 land use images were converted to grids (Figure 3 and 4) using "imagegrid" in Arc. They were then clipped to the soil type coverage (soil coverage is explained below).

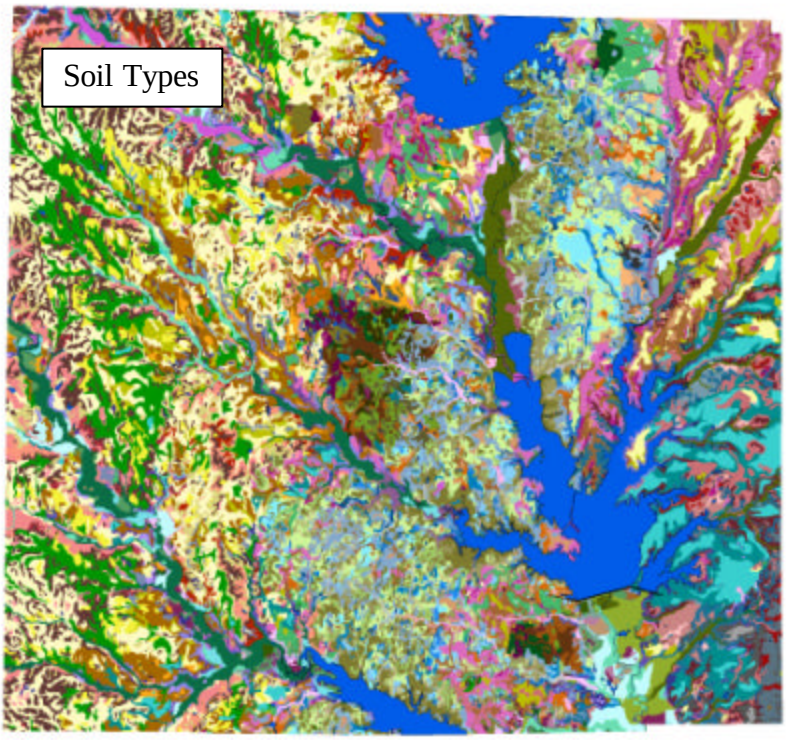



1988 Land Cover
Open Water
Wetland
Forest/Riparian Forest
Herbaceous Rangeland
Shrub and Brush Rangeland
Mixed Rangeland
Cropland and Pasture
Transitional Cropland and Pasture
Highly Maintained Vegetation
Urban- Highly Vegetated
Urban- Sparsely Vegetated
Bare Ground
Unknown/Shadow
Cloud

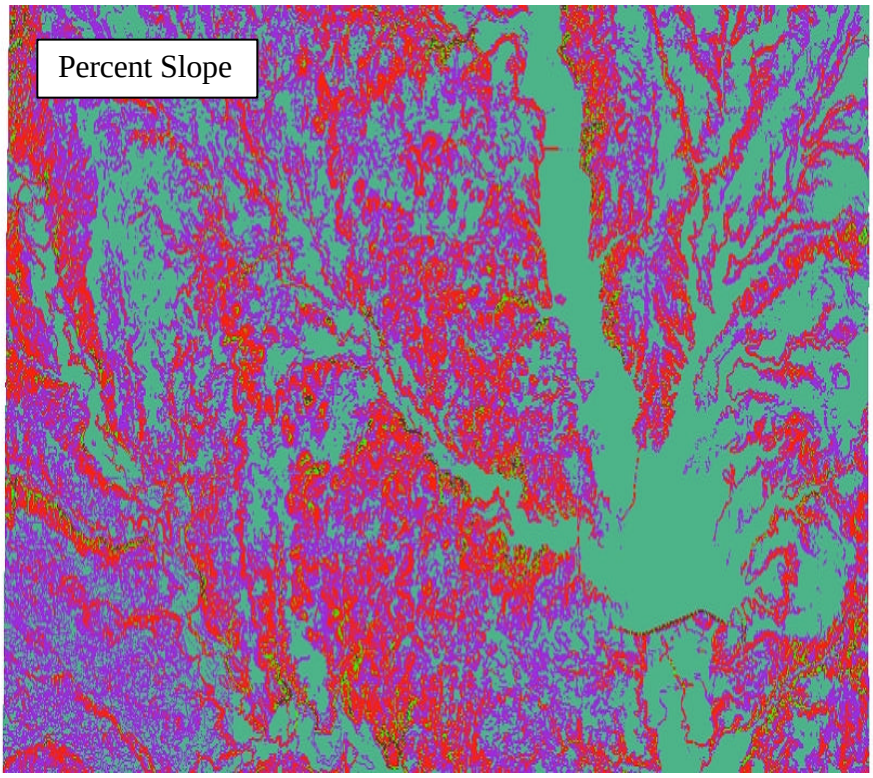


A detailed soil map for Denton County, based on the soil series, was downloaded from the Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) database. The polygons of this map were identified by their MUID numbers. The soil coverage was unzipped and imported into ArcInfo. The coverage was then re-projected to UTM zone 14 NAD 27. We created a display in ArcView. Then, the Denton County boundary shapefile was created from the soil coverage. Then, the boundary shapefile was converted to a coverage in ArcInfo. The soil map was then converted to a grid (Figure 5) at 30-m resolution, with a soil type and permeability value for each cell. The soil classification numbers were altered (six zeros were appended to the numbers) during the conversion process. These numbers were recalculated and then checked against the soil survey book to ensure accuracy. Soil types and permeability values

were added to the attribute file of the soil coverage, via a relate table, according to the Denton County Soil series in the Soil Survey Book of Denton County.



Data on elevation and slope was obtained from USGS Digital Elevation Model (DEM). We used the USGS topographic map (1:24000) to determine which DEMs were needed for Denton County, and then they were cross-referenced with the USGS index. These DEMs were digitized 7.5-minute USGS quadrangles at 30-m resolution. The seamless DEMs were then downloaded from Chart Tiff CD ROMs, and then they were appended to create a single DEM for Denton County (Figure 6). The “sink” and “fill” functions in Arc were applied to the Denton County DEM to eliminate any “holes” in the data. Percent slope for each cell was determined in ArcGrid by applying the “slope” procedure. The slope procedure produced to many individual values so the grid had to be re-classified with the “slice” procedure in ArcGrid. The slope values were grouped into 5 categories: 0-5%, 6-12%, 13-30%, 31-45%, and 46-150%. A few slopes were very steep, so the last category was large enough to cover these values.



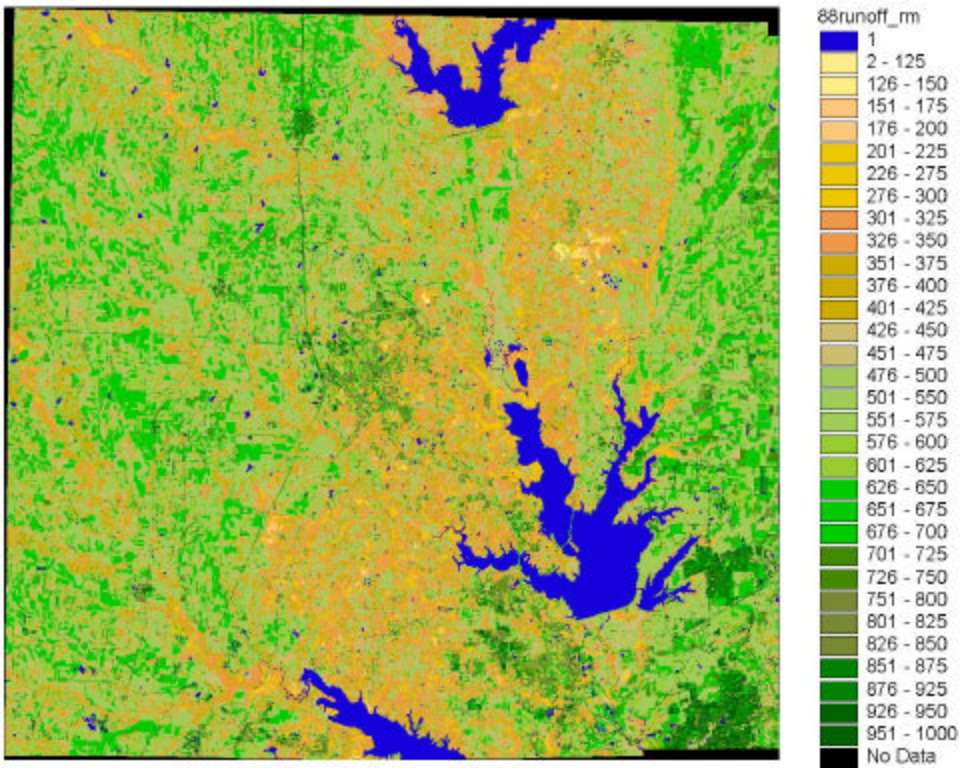
All data layers were clipped to the Denton County boundary of the soil map coverage, to ensure consistency. Since most of the data was available in UTM Zone 14 projection, anything that was not was re-projected to match. Final results were displayed in UTM Zone 14 projection.

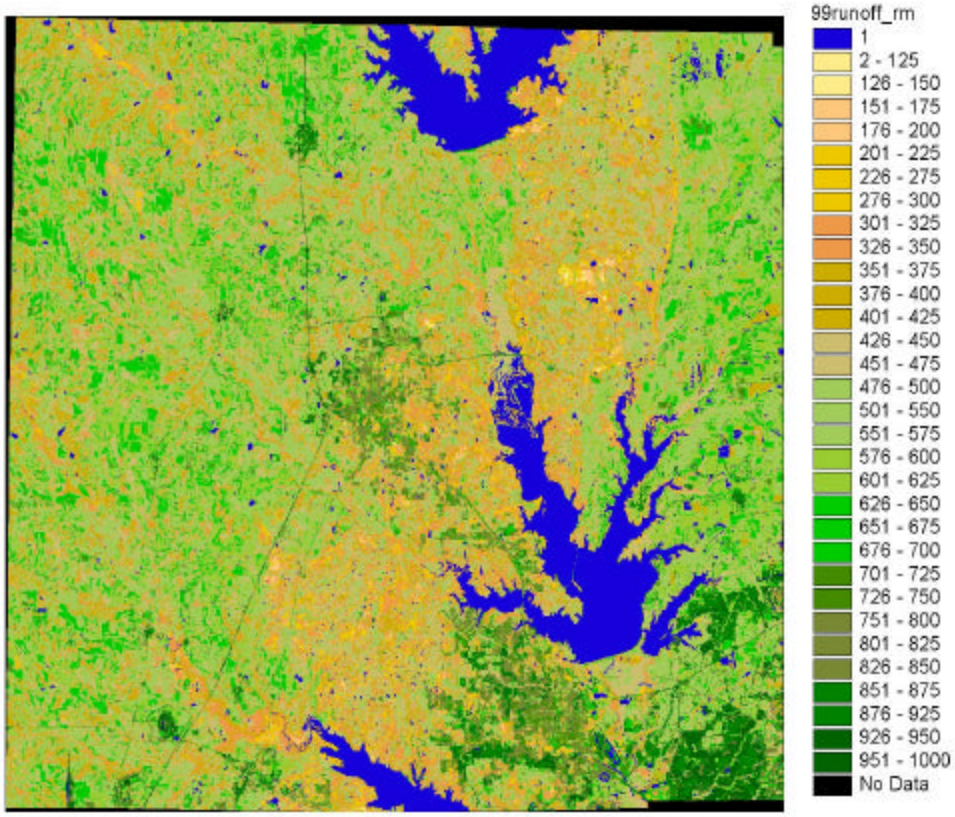
Data Analysis

We wanted to assess runoff potential between 1988 and 1999 in Denton County, and created a model to determine the runoff potential. Runoff coefficients were given to the various classes in our soil, slope, and land-cover grids. These coefficients were determined by the individual pixels, and coefficients were applied to all grid classes. The model that was created was simple and was designed only to gage the amount of change in runoff potential due to urbanization and land-cover change. Other factors affecting the amount of overland flow from a watershed, such as evaporation, transpiration, and soil moisture are not considered.

The relate tables were built for all four grids (2 land-use grids, soil grid, and slope grid). The relate tables were a bit different between 1988 and 1999 because one of them had categories of “clouds” and “shadow”, and the other image had an “unknown” category. So, we had added “clouds and shadows” to the “unknown” category in the other image.

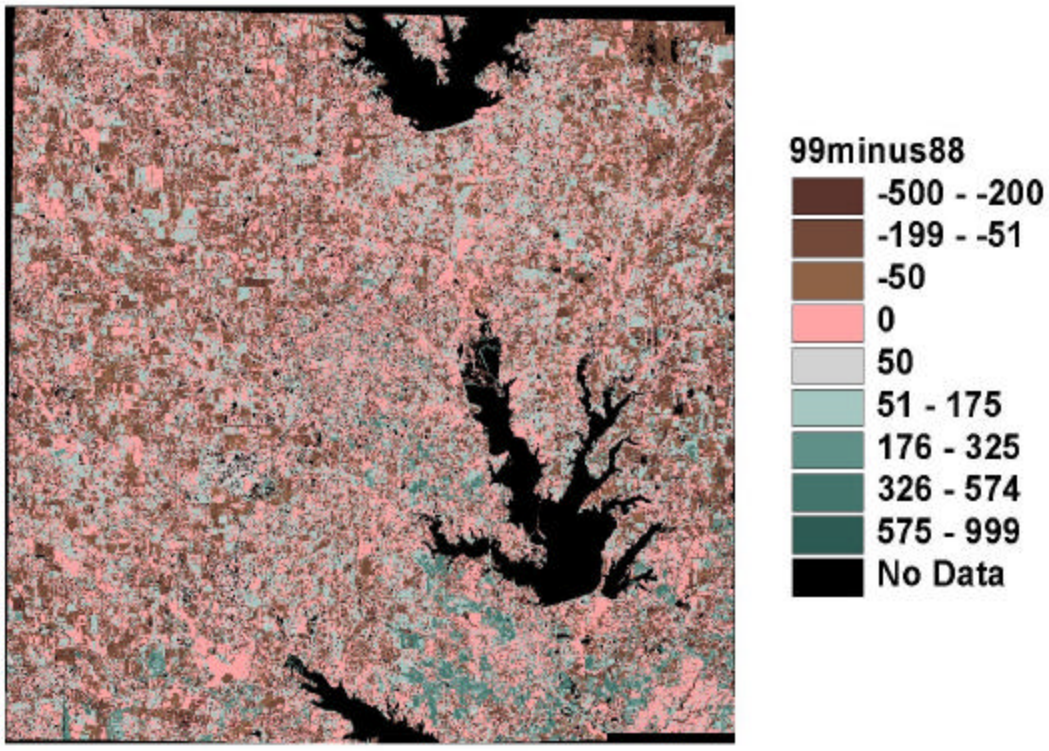
A literature search for runoff coefficients that fit our situation produced primarily ranges as opposed to specific values (Bruce and Clark, 1969; Gray, 1973; Sharp and Sawden, 1984). Most authors based the primary value range on the land-cover category and increased or decreased the value within the range in response to changes in soil type and slope. For our model we did the same; the land-cover categories carried the primary runoff coefficients, calculated as the median of the range for the particular category. The soil and slope grids contain values designed to modify the primary runoff coefficient up or down, within the category’s range, depending on the permeability of the soil and the percent slope. The values for open water, wetlands, clouds, and shadow were given a value of 10 to distinguish them as pixels to exclude from the analysis. A runoff potential map was created for both 1988 (figure 7) and 1999 (figure 8). Map algebra was conducted on the images, taking the values of 1999 minus 1988 values. This gave the runoff potential change (see figure 9).


88runoff_rm
1
2 - 125
126 - 150
151 - 175
176 - 200
201 - 225
226 - 275
276 - 300
301 - 325
326 - 350
351 - 375
376 - 400
401 - 425
426 - 450
451 - 475
476 - 500
501 - 550
551 - 575
576 - 600
601 - 625
626 - 650
651 - 675
676 - 700
701 - 725
726 - 750
751 - 800
801 - 825
826 - 850
851 - 875
876 - 925
926 - 950
951 - 1000
No Data


99runoff_rm
1
2 - 125
126 - 150
151 - 175
176 - 200
201 - 225
226 - 275
276 - 300
301 - 325
326 - 350
351 - 375
376 - 400
401 - 425
426 - 450
451 - 475
476 - 500
501 - 550
551 - 575
576 - 600
601 - 625
626 - 650
651 - 675
676 - 700
701 - 725
726 - 750
751 - 800
801 - 825
826 - 850
851 - 875
876 - 925
926 - 950
951 - 1000
No Data

Results

Our model indicated that 32.7% of Denton County had an increase in runoff potential. 33.4% had a decrease in runoff potential, and 33.9% had no change in runoff potential. The value of the 'Sum(change * Cell-count) = +8021500' shows a positive overall increase in runoff potential for Denton County. Figure 10 shows that all the categories below the zero category are positive values, and these are areas where there is an increase in runoff potential. The increase in Total Runoff Potential for the county is 0.6%.



Discussion

Percentage-wise, we had a decrease in runoff potential, but the actual Total Runoff Potential had an increase. The majority of the increase in runoff potential is by the lakes and is

due to urban development. Most of the areas with the highest runoff potential were found near Lake Lewisville, which is where the citizens of Denton County receive their drinking water. Increase runoff also means there is an increase of oil from streets, fertilizer, and pesticides from farms that can runoff into the lake.

There are short-term changes in surrounding land-use areas around the city of Denton that makes the Runoff Potential change constantly. Over the last ten years, rural development has been changing – but these are short-term changes. The biggest change in Runoff Potential appears to be the permanent urbanization because it is a long-term affect. The county as a whole has areas of increase and decrease in runoff potential. The small amount of 0.6% as an increase is not too large, but further research is recommended to look at the city of Lewisville in more detail to see how the runoff potential has changed in just this area alone.

The effects of increased urbanization on runoff potential could be a major concern for local flood control managers. Flood control systems to manage urban runoff include dams, open channels, and underground storm drains. The City of Denton should want to learn about increased runoff potential affecting flood rates, stream discharge, and bank erosion because of the affect it will have on the citizens of Denton and the future of flood impact on Denton. With increased urbanization, there are many problems city officials may overlook that need to be addressed before the problems get out of hand. The lack of water for the growth of Denton County will be a problem, especially if Lake Lewisville becomes polluted because of the heavy runoff occurring around the lake. As citizens, we need to pay close attention to the changes in Denton County, and make sure that urban growth does not affect our health and our future water quality.

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