An Investigation of Geographic Information Systems in Comprehensive Land Use Planning

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Abstract

Contradictions are deeply ingrained in any form of planning and inherent in policy development and operations. Land is a valuable commodity in a finite supply thus land use planning can be a complex quagmire of competing ideals and intense power struggles. Land use planning has become an increasingly complex and dynamic profession that depends on the working relations from all facets of society. Comprehensive planning provides an opportunity to state and develop these beliefs into general goals and policies for a community over a prescribed amount of time. Maintaining and continually updating these plans is an ongoing process in defining goals and aspirations with varying problem solving methodologies. Sorting through the varying agendas and ideas often falls on decision makers in a bureaucracy, who have to base their thoughts on their best judgement. These conclusions can be greatly enhanced using visual representations of the prescribed subject matter.

Winona County's Planning Commission has chosen to implement Geographic Information Systems (GIS) as a basic tool that will assist them in updating the Current Comprehensive Land Use Plan. Using GIS provides an avenue to actively view data in a spatial context that will enhance their cognitive reasoning processes and make more sense than archaic textual facts and numbers. The Planning Commissions wanted to query various spatial data and determine how the land is being used under the current guise of regulations and policies. Using this data will allow for accurate visual representations of what is occurring in Winona County at a township level. A GIS pilot project was initiated to run various analyses on land use issues to verify its usefulness in the Comprehensive Plan Process. Dresbach and Whitewater Townships were selected as the pilot study areas. For the purpose of this paper Whitewater will be discussed further. Figure one displays the thematic layout of Whitewater Township. The pilot project was to include all steps from accessibility and cost of data to analysis and output of useful data that will be used in the Comprehensive Land Use Plan update process.

Introduction

Counties throughout the United States are dealing with an increasing number of sociological and physical challenges directly caused or influenced by the changing landscape patterns of the twenty-first century in the United States (Hammond, 1996). The humanized environment is redefining the natural and rural characteristics of areas faster then many local governments can endure or perceive. With the idealized embodiment of rural living gaining

popularity, pressures on the predominately natural and agricultural areas are increasing exponentially. This social phenomenon, caused by rising taxes, displeasure with the urban environment and desire for permanent residence away form established cities and towns, has driven resources and services far beyond planned thresholds. Areas lacking in official planning policies, or operating with out them are or will be non existent. Today, counties like Winona County, must forge ahead with updating and revising outdated plans that will protect and preserve both the environment and economic worth of all land within it's borders (Catanese and Snyder, 1988).

The need for comprehensive or master plans with long-term implications was reinforced by the courts of California in 1915 with the case of Hadacheck vs. Sabastion (Smith, 1979). This case established the legality of zoning as a way for establishing consistent property values (So et al., 1979). By the 1920's, zoning was being used as a way for protection of established land uses and as a way to direct changes in land use by local governments (Knox, 1994). In 1926, the U.S. Supreme Court upheld the constitutionality of zoning with the Euclid, Ohio vs. Ambler Reality case (Knox, 1994). Consequently, comprehensive plans and zoning ordinances were established across the country as a way for planning future growth and guiding development (Branch, 1988). Developing comprehensive land use plans can help determine the best or most suitable sites for housing, industry, commercial uses, agriculture, recreational, open spaces and areas that should be preserved (Hammond, 1996).

Land use planning in the United States is actually done largely through zoning. Zoning involves determining the best or most suitable uses for all different parcels of land in a given area (Miller, 1985). This method is primarily concerned with preservation of long-term development of an area. Planning is a comprehensive strategy that is designed to help achieve local and regional objectives (Branch, 1988). A land use plan is also used as a way for guiding and administering zoning ordinances for regulation of land and future locations of facilities in an area (Banovetz, 1984). The requirements from different areas may vary, but they must be consistent within a zone (Meshenberg, 1976). In addition, an ordinance will further subdivide the zones into different classifications with varying standards that shape each particular area (Johnson, 1989). Without these measures of control, many areas in the United States would be chaotic, haphazard assortments of structures lacking identity and direction (Campbell and Feinstein, 1996). The connotation is that land use planning should be used to improve the environment in which we all reside (Hammond, 1996). Translating good planning policies though has proven difficult if not impossible because of the vast and varying groups that involve themselves with the planning process.

Planning must integrate professional technicians, planners, planning commissions, elected officials, township governments and the general population to compose and develop plans that represent the views of the majority (Isberg, 1975). The problem with developing these plans for land use tends to occur with the fact everyone has a different idea on how the land should

be used or is being used. In the case of land use planning these opinions are stratified across generations, socioeconomic classes, ethnicity and location factors and ideologies (Cullingsworth, 1993). Rights groups often take extreme views regarding the environment, property rights, government, development and recreation. They can also play a crucial role in bringing issues to the forefront that need to be addressed (Levy, 1997). All of these players bring their own personal agendas and opinions to the planning process (Cullingsworth, 1993). The views of land use planning very widely throughout the different segments of society because it is viewed as placing restrictions on personal property. Decisions makers in a county or townships have a vast amount of opinions to evaluate and consider in regards to land use.

Geographic Information Systems provides the necessary means to forecast or analyze information in a spatially viable manner for a prescribed area. Modeling with GIS provides useful visual representations of the environment or jurisdictional areas. Developing a land use planning model should include all major variables that considers and integrates information as a medium for accurate, factual and visually shared perceptions for responsible decisions. The hope for a land use model is to provide spatially visible and viable results that can be forecasted to a township or the entire county. Using a GIS system also allows for the merging of data to view the interconnectedness of the variables commonly associated with land use planning. Models will help put issues into perspective and give each issue relative importance. From a county or township view modeling for a Comprehensive Land Use Plan will allow Planning Commissions and County Boards to take inventory by township or county level what currently exists and how the land is affected by current policies, goals and regulations.

The Winona County Planning Commission decided to implement a GIS in the comprehensive land use process. The Commission hopes to visually understand and portray the working relationships of the land and policies and regulations that prescribe the particular uses. Inventory modeling provides need information that portrays how much of a particular resource will or could be affected. This procedure allows for the most common method of analysis, known as observations that assist in providing sensible land use decisions that work. GIS also allows for an area to be broken down into smaller jurisdictions, areas or governmental sections. In the case of land use planning, it allows township level government to be looked in an individualized manner. Displaying data provides an invaluable, often under utilized awareness or visual inventory of what is occurring in the county or in a particular township. GIS can and will provide policymakers an ever “present backdrop” for evaluating particular thoughts or specific recommendations as they pertain to the entire area (Branch, 1985).

This paper looks at the areas of Winona County at a township level, specifically Whitewater Township. (Figure 1) Throughout the Comprehensive Plan update process Township Officers and local residents have stressed the need for localized planning at township levels. Many residents and local leaders felt that

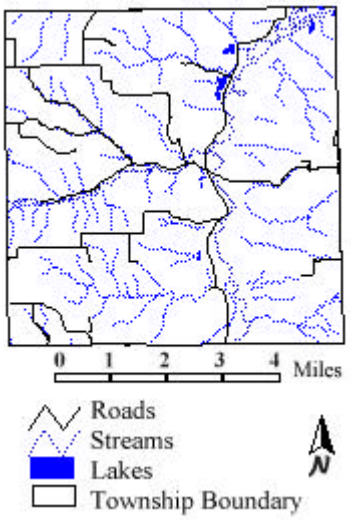

Figure 1. Thematic View.

attention needs to be paid to the individualized townships and see exactly how the bureaucracy has effected the way land is used or will be used in the future. As a result, the Planning Commission decided that studies would be done at a township level to characterize the nineteen unique Townships of Winona County. Analysis with a GIS was used to take inventory of the amount of land used or effected by the current regulations and policies. The hope was to see how the land is currently regulated and provide an avenue for potential change to further enhance the environment and development patterns in Winona County.

Through the past six months, main themes of analysis developed through a variety of Work Sessions and public input. The concern was that government makes unresponsive decisions pertaining to land use in Winona County. The Planning Commission became concerned with how much developable land is remaining in Whitewater Township after all current land use restrictions are subtracted out. The interest has been created by vast public input and the Department of Natural Resources involvement. Factors that received the most importance were slope percentage, publicly held land, road setbacks, floodplain restrictions, and stream setbacks. Other consistent factors that contributed to the subtraction model were actual lakes, wetlands and other natural or manmade features. The model was further augmented by analyzing soil types that could directly effect development trends and patterns. Creating two digital coverages from the Geological Atlas concerning Ground Water Pollution and Sinkhole Susceptibility provide a strong visual image of the Karst topography existing in Winona County and the problems that may develop.

GIS implementation also allowed the opportunity to analyze the interest of creating a separate zone encompassing either recreational land or forested land. How this would effect agriculture and other patterns of development was of concern by Planning Commission members and local residents. Breaking the study down further allowed for inventorying past land cover types and presently existing conditions in Whitewater Township. Creating these coverages also allowed the portrayal of agricultural land in terms of present amounts and potentially impacted land with a creation of a new zone creation.

Methods

Data Collection

Data themes where obtained in conjunction with the Department of Natural Resources (DNR), Minnesota Department of Transportation (MNDOT) and the Federal Emergency Management Association (FEMA). These sources provided a comprehensive

collection of spatial information pertinent to Winona County land use issues. All coverages were developed in ARC/INFO and exported into shapefile formats compatible with ArcView 3.0a. All themes were found to be projected in the Universal Transverse Mercator (UTM) in Zone 15, NAD 83. They all were at a scale of 1:24000, which provided clean overlay procedures when implementing these data sources.

Winona County's Planning and Zoning Department also contributed to the overall data collection, by providing the current zoning coverages that would be used to identify how the land is currently regulated. The Planning and Zoning Department also provided the parcel coverage of Whitewater Township, at Plat Book level accuracy. These coverages were projected in UTM Zone 15, NA83 at a scale of 1:24000.

Creation of Coverages

The Environmental Management Technical Center (EMTC) scanned in Groundwater Pollution Susceptibility and Sinkhole Probability from the Geological Atlas for Winona County. The data was projected as a tagged image format in NAD27 at a scale of 1:100,000. The plates were created by heads up digitizing the various lines of the geo-referenced tiff images in ArcView 3.0a. These themes were then converted to decimal degrees using projector extension. The datum was converted from NAD27 to NAD83 using datum extension. The themes were then converted to UTM Zone15, and remained at a scale of 1:100,000. A points coverage was also created that represented estimations of current sinkholes that were either open or filled. This theme was created in the exact manner as the two previous themes with the only exception this was a points coverage that represented centroids of sinkholes.

Field Survey

Visual data was collected from Whitewater Township as a means for familiarization of the current land uses. References were video taped using a digital recorder to provide accurate visual pictures of the Township's general topography, natural features and current land uses. The tour also provided an opportunity to develop a working understanding of the Karst topography that is attributed to Winona County unique landscape characterization.

Data Manipulation

Data at this scale provides an overly generalized display of actual geological activity in Winona County when the other data is overlayed or analyzed. There are no claims of on the ground accuracy. The study was designed to show generalized land use patterns that occur at a township level. The purpose of spatial visualization is to incorporate all current coverages assembled or maintained by the County Planning and Zoning Department for informed decisions based on spatial perception.

Results

Data Discrepancies

Most of the coverages for the township studies are projected to UTM, Zone 15 at a scale of 1:24000. It is important to note, that data at this scale is not going to provide exact numbers in analysis.

The coverages in this project are being used to provide general information for planning purposes.

The Plates from the Geological Atlas that were digitized in, are at a scale of 1:100000. This provided an over generalization of the township's actual features when studying sinkhole probability and potential ground water pollution. These themes also included inaccuracies at the northern edge of plate due to inaccurate reference points. This was noted during the creation of the themes, and was accepted for use. The themes are only being used for general information, and extreme accuracy was not needed. Other factorial errors in the Geological Plates stem from the original hand drawn production of the map series in 1981. These plates can only be used as reference maps or overlays for the purpose of avoiding potential land use problems in the future.

Spatial Analysis

The first question the planning commission asked is how much land resides on slope above fifteen percent. Using 1:24,000 USGS DEMs as our source data, it was possible to create an arc coverage with slope percentage as an attribute field. To obtain the numbers needed, the theme was queried, selecting out all areas over fifteen percent. The analysis showed about 8500 acres are over fifteen percent. (Figure 2)

To add to this analysis, the planning commission asked how much land resides on slope above fifteen percent that is covered with forest. This information is crucial as the commission considers creating a new recreation or woodland zone to prevent development and assist farm owners in lowering or stabilizing their taxes. To find this

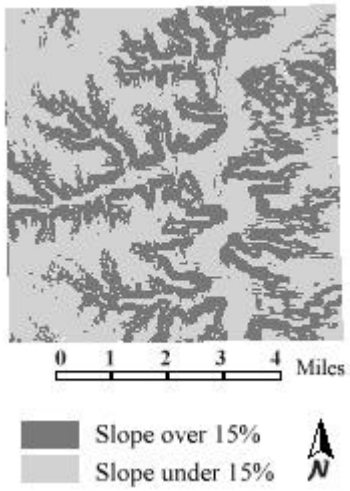

Figure 2. Slope of Whitewater Township.

information the intersect command was used within X Tools in Arcview. This created a new theme of areas that were above fifteen percent and covered with trees. This new theme covered over

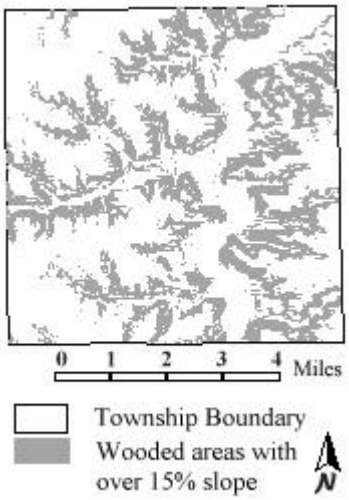

Figure 3. Possible areas for new zone.

6600 acres. The visual and tabular output will be used in the decision process for creating this new zone and provide the Planning Commission with a shared spatial perception of the Township (Figure 3).

The Planning Commission also wanted to know how much land was currently under development regulations in Whitewater Township. All County wide coverages were clipped down to Whitewater Township jurisdictional lines. This provided an opportunity to isolate the various thematic features within the Township's boundaries for analysis. This also allowed for a spatial recognition of how the Township is arranged in terms of transportation, land cover, hydrology, topography, soil types, and zoning. The data was referenced using the Public Land Survey System (PLSS) as a familiar reference and point of scale for the Township. Digital Ortho Quads were also used to further enhance and provide a real world perspective of the Township.

A polygon theme of the entire Whitewater Township was used as the starting point for this analysis. The Whitewater Township contains approximately 21000 acres. From this theme, all land under current regulations was removed. First the land that was over fifteen percent slope was subtracted. This process removed over 8500 acres leaving approximately 12500 acres of land under fifteen percent slope.

Next the 500 year floodplain boundaries were removed from the total acreage, This bought the total acres regulated to just under 50% of the total land in Whitewater Township.
Major and minor collector roads and their associated setbacks were then subtracted from the remaining land area. The transportation themes only accounted for a few acres of the regulated land. This is mostly in part to the roads being located in the floodplain areas due to minor slope.

Finally, protected waters and the buffers representing set backs from the lakes were removed. After the last regulated features were removed, Whitewater Township was left with just over 10000 acres of land that was not confined by land use regulations.

The analysis process showed that over half of the land in the Whitewater Township is currently under development restrictions and regulations, and is not developable. (Figure 4)

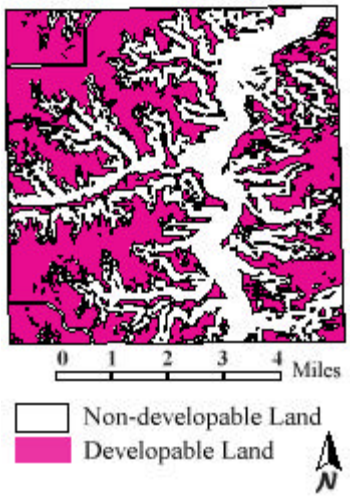

Figure 4. Developable land.

On top of these restrictions and regulations, the remaining acres are even further controlled by the "quarter-quarter" rule. This rule allows only one non-farm structure per quarter-quarter section of land (one non-farm dwelling per forty acres). Further analysis would have to be performed by applying parcel data to the "buildable" land to determine how specific residents or landowners would be effected.

The model was further enhanced by performing a visual overlay of the two geological plates. The Groundwater Pollution Susceptibility and the Sinkhole Probability themes offer a deeper view into the complexity of land use issues. These two factors are very important to consider in a site assessment or development analysis model, due to the

information they provide on environmental impact and potential developmental hazards. The Planning Commission also wanted to understand the change in land cover type from pre-settlement times to current times (Table 1 & 2). Running this query provides

Table 1. Summary of presettlement vegetation cover

LAND_COVER (1847 - 1908)	ACRES
Aspen-Oak Land	1970.00
Big Woods - Hardwoods	7890.00
Oak Openings and Barrens	9440.00
River Bottom Forest	1700.00
TOTAL:	**21000.00**

Table 2. Summary of 1990 landcover

LAND_COVER (1990)	ACRES
Bare Rock	3.10
Cultivated Land	6260.06
Deciduous Forest	11870.27
Expose Soil/Sandbar/Dune	1.30
Farmstead / Rural Residence	130.35
Grassland	2330.45
Grassland-Shrub-Tree (decid)	120.39
Other Rural Development	2.90
Water	150.99
Wetlands	110.67
TOTAL:	**21000.00**

important information to decision-makers and citizens of how the land in Whitewater Township has become fragmented over the past ninety years. This was also a useful exercise in demonstrating how humans really can and will alter the environment to fit their needs or desires. Furthermore it provides a working example of the working land trends and characterizations of the Township.

Soil types provide important information on what land can or should be used for. The data provided by the soil survey contains data that depicts soil characteristics and behavior in regards to various uses. Using the soil data from the Department of Agriculture afforded the opportunity to query data to identify those areas with soils that are hydric and susceptible to flooding. Separate coverages of prime farmland versus non-prime farmland were created to show the two distinct classes in a visual format. It was found that over 15600 acres reside in non-prime farmland, while another 2370 acres of this non-prime farmland is labeled as hydric soils that is often unbuildable. Just over 5100 acres of the Township are considered prime farmland under the Crop Equivalency Rating (CER) classification scheme (Figure 5). This rating is based on crop productivity and soil conditions that depict potential agricultural worth in terms of land. If this method is deemed unacceptable, the definition of prime soils in terms of agriculture will need to be redefined or made less stringent. The other option would be for the Planning Commission to explore other rating systems from the

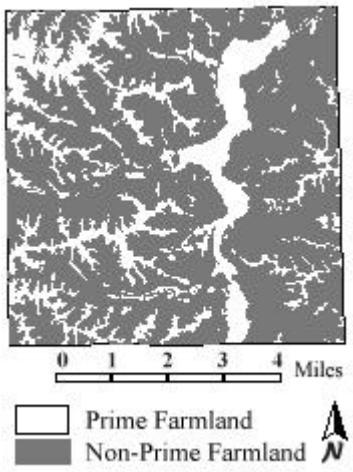

Figure 5. Farmland ratings.

Soil and Water Conservation. Non prime land is also a valuable resource for livestock operations and was not

considered in this study. This was a variable that could greatly effect what is considered prime farmland when crop and livestock farming are combined.

Th*e potential for use*

The GIS showed great potential for use in both the comprehensive plan and the everyday decision processes of those affiliated with the planning process. We were able to do fast and accurate queries on land use items in a fraction of the time it would take just a few years ago. Careful planning for these current land use trends and those to follow will save municipalities and counties millions of dollars if careful study of trend data is used concurrently with a Geographic Information System (Campbell and Feinstein, 1996).

Overview of results

Each one of our queries provided the information that the planning commission wanted. We packaged our data and analysis is an easy to use directory that will allow for easy repeats of the steps we followed. Winona County will now use our data and analysis to run queries on the entire County. Hopefully this new, fast, and accurate data will lead to quicker and more informed land use planning decisions. In order for this to happen on a Countywide basis, further data layers will need to be developed and maintained.

Discussion

With local planning departments limited amount of time, money, personnel and information developing a strong, well done comprehensive land use plan can be a difficult task. As a result, land as a resource is often squandered by under utilization or over use that cause environmental degradation (Hammond, 1996). Lack of planning leaves growth unchecked and results in careless development that can limit or promote development creating a hodgepodge landscape that destroys the character of an area (Knox, 1994). The artificial boundaries that we have created politically create further hardships on the environment because they bear little resemblance to the natural boundaries that occur such as watersheds, ecosystems and viewsheds (Hammond, 1996). This results in plans that overlap or do not mesh with one another causing difficulties in overprotection or under protection that can leave a specific area vulnerable to land use difficulties either physically or politically (Miller, 1986).

What needs to be done in Minnesota like other states is develop a statewide advisory council of government (COG). There main responsibility would be to help develop and plan a statewide land use plan that facilitates the use of all state land both publicly and privately in a responsible manner. There are many regional agencies that exist throughout the state that also need to pool there efforts into developing plans that work with one another rather then against each other. Currently in Minnesota different counties take different stances on development, they all need to come to some common agreement over how the land in this state could best be used. Using a COG is not the best answer because they to are under funded and usually under staffed. The state of Minnesota needs to be broken into regions that would then have officers from each county appointed who could

then develop a common land use plan for the entire state. Although for this to occur the citizens of the state would have to become a great deal more active in the political arena. As it is now counties draw up most plans with very little input from its residents because many of them just are not concerned about the big picture. Most people today are only worried about what their little area looks like. We as society need to start becoming more aware of the problems and complexities of the world that we live in. Planning is necessary for the survival of our society in the way that citizens consider advantageous (Cullingsworth, 1989).

To further improve the land use planning process there needs to be a large investment in Geographic Informational Systems. By creating visual representations of the world around us along with the pertinent data that is attributed to these features we can better understand what is occurring on the land. Having this type of data readily available will improve many economies, environment and resolve many land use disagreements by graphical representations. Data that is readily available will improve the overall effectiveness of the land use planning procedure. Land as a resource is our most important asset and the wise utilization of this resource should be demanded and expected.

Acknowledgements

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